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ABSTRACT

The major findings and generalizations of nine separate experiments summarized in this report have come out of a program of research on human factors in telecommunications and teleconferencing systems at Johns Hopkins University. These findings, already published in greater detail in the open literature, relate to (1) how people naturally communicate with each other when they are required to solve problems of various kinds, (2) how interactive human communication is affected by the machine devices and systems through which people converse, and (3) what significant system and human variables affect interactive communication. A bibliography of the 13 studies published by this program is provided. (CMV)

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HUMAN FACTORS IN TELECONFERENCING SYSTEMS

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INTRODUCTION

This report describes briefly some of the main findings that have come out of a program of research at The Johns Hopkins University on human factors in telecommunications and teleconferencing systems. It has always been my policy to publish our research findings in the open periodical literature so that they are readily and freely available through ordinary library facilities to all interested persons. For that reason, it would be redundant to give in this report a complete summary of all the findings that have come out of my research program. One important function of this report is, rather, to provide a complete bibliography of all the studies we have published so far as a convenience for those readers who are interested in this area of research.

A research program in any established laboratory is a continuous process that cannot be segmented into independent and autonomous units. Nor can individual research studies always be terminated to correspond exactly to administrative, or budgetary time units. Although the program of research at Johns Hopkins has gradually shifted emphases throughout its existence, it is, nonetheless, a continuous process. The findings summarized in this report are for those projects that have been completed, and that have been published in the open literature on the termination date of this research grant--30 November 1976. This report does not cover research studies in various stages of completion, or reports in various stages of publication, on that termination date.

This research program has produced an extremely rich series of findings that could not be fully covered in a report such as this one. Details of findings are available in the published literature. Rather, this report extracts some of the most interesting findings of the several studies referred to here, and integrates those findings into a series of broader generalizations.

In discussing the findings of the Hopkins research program, I do not mean to suggest that it is the only one that has been concerned with these problems. A great deal of very good work on person-to-person communication, and on human factors in telecommunications, has been done in other laboratories. Prominent among them are the Communications Studies Group at University College London, Bell Laboratories in the United States, Carleton University in Canada, and Bell Northern Research in Canada. While acknowledging the fine work of those other laboratories, this report is frankly what it says, a report of work done at Hopkins.

Purpose of the Hopkins Program

The goals of the Hopkins program are to discover (a) how people naturally communicate with each other when they are required to solve problems of various kinds, (b) how interactive human communication is affected by the machine devices and systems through which people converse, and (c) what significant system and human variables affect interactive communication.

All the research conducted in the Hopkins program has been done by having people communicate with one another in various ways. Since they originate from basic laboratory research, the findings are hopefully relevant to several areas of application. Foremost among these areas of application is the design and use of telecommunication and teleconferencing systems. The findings are, however, only slightly less relevant to interactive man-computer systems. And, finally, our data have some bearing on the conduct of face-to-face meetings and conferences. The purpose of the Hopkins program, however, has been to produce basic data about human interactive communication and not to concern itself directly with specific areas of application.

Reports and Studies Covered

Altogether nine separate experiments have been completed, analyzed, and reported from this program. They have resulted in thirteen publications, a complete list of which appears at the end of this report.

INTERACTIVE TELECOMMUNICATION DEFINED

In communication research it is important to make a distinction between interactive and unidirectional communication. For years psychologists and other scientists have been concerned with the effectiveness of unidirectional modes of communication, such as highway signs, books, lectures, and television broadcasts. In unidirectional communication, the person to whom a message is addressed is a passive recipient of information. Nothing that he does or says affects the communicator, the communication process, or the content of a message.

In interactive communication, by contrast, the participants are both senders and receivers of information. Communicators, the communication process, and the contents of messages can be, and usually are, affected by all the participants. Conferences, arguments, seminars, telephone conversations, and man-computer dialogs are examples of interactive communication. This paper is entirely concerned with interactive communication.

Telecommunication means simply communication at a distance. Although our interest is primarily in telecommunication, I shall have a great deal to say about face-to-face communication because it is the standard against which the effectiveness of mechanically- or electronically-mediated communications are usually compared.

THE RESEARCH SETTING AND LABORATORY

In considering modes of communication it is interesting to ask first what human skills are used naturally in person-to-person communication. The list is surprisingly short. Everyone, even the inarticulate and dumb, can convey information by body movements--postures, gestures, and facial expressions. Virtually everyone can speak one of the natural languages--perhaps not grammatically, but fluently. A majority of people have at least some elementary level of competence in writing. Finally, a respectable number of people know how to type and even some people without typing experience seem to be able to approach the keyboard and peck out acceptable messages. But these few different kinds of skills exhaust the list.

Our experiments have tested four different channels of communication that are the mechanical or electronic counterparts of the four forms of natural human communication that I have just described. The four channels are video (the picture part of television without the voice), voice, handwriting, and typewriting. Three of the four basic channels have been tested singly, and all of them have been tested in various combinations. The individual channels or combinations of them are referred to collectively as modes. We have tested as many as ten different modes in a single experiment (Ochsman & Chapanis, 1974). As a standard of comparison we typically rely on normal unrestricted, face-to-face communication, which for several reasons, we have called a communication-rich mode.

The laboratory in which most of our experiments have been done consisted of two adjoining rooms connected by a soundproofed double door (Figure 1). The wall between the rooms also had in it a large double-glass panel, which could be covered with an opaque screen so that the persons in each of the rooms could not see each other. When the panel was not covered, the participants could see each other and could converse freely through a microphone and loudspeaker, even though they were separated physically. In some of our experiments, subjects have actually been face-to-face, or side by side, in the same room.

Figure 1 shows teletypewriting and telautograph machines. These machines are linked in such a way that anything typewritten or written

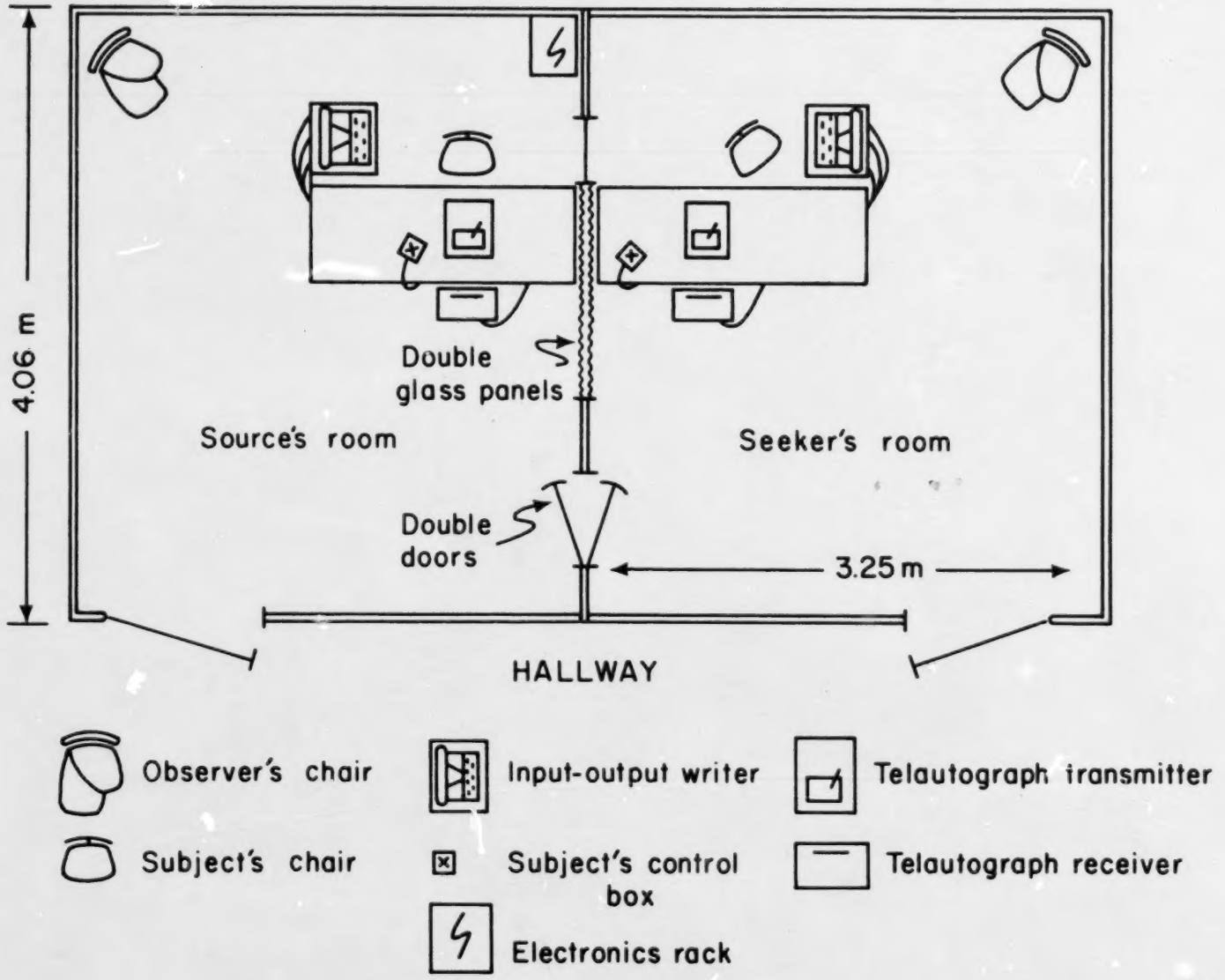

Figure 1. The two experimental rooms and associated equipment used in most of our earlier work.

in longhand on a machine in one room is simultaneously reproduced on the other. Video cameras and monitors enable us to duplicate closed-circuit television or to use either the video or audio channels separately.

For one of the experiments discussed in this report (Krueger, 1976), we used four adjacent laboratory rooms in the Psychology Department (Figure 2) for tests in the televoice and teletype communication modes, and a room (Figure 3) built especially for conference research in the Department of Social Relations at The Johns Hopkins University for conferences of 2, 3, or 4 persons.

About a year ago, we expanded and redesigned our laboratories as shown in Figure 4. The new arrangement permits us to test as many as four persons in as many different rooms. Communication facilities among the rooms allow all persons to communicate with all others, or allow only certain communication links to be used.

PROBLEMS

In our research we have tested two main kinds of problems: co-operative and conflictive. Altogether we have compiled and tested nearly 20 different problems of both kinds.

Cooperative Problems

Our cooperative problems have been carefully chosen to meet several important criteria:

(1) The set of problems samples a wide range of psychological abilities. For example, some problems are entirely clerical paper-and-pencil tasks, some involve mechanical manipulation, others require careful attention to detail, and others make use of still other psychological skills.

(2) The problems are representative of tasks that are the subject of interactive conferences or meetings, or that might be addressed in such meetings.

(3) They are of recognizable and practical importance in every-day life--they are not abstract or artificial problems of the type often constructed to measure hypothetical psychological processes.

(4) They have definite, recognizable solutions and the solutions can be reached within approximately an hour.

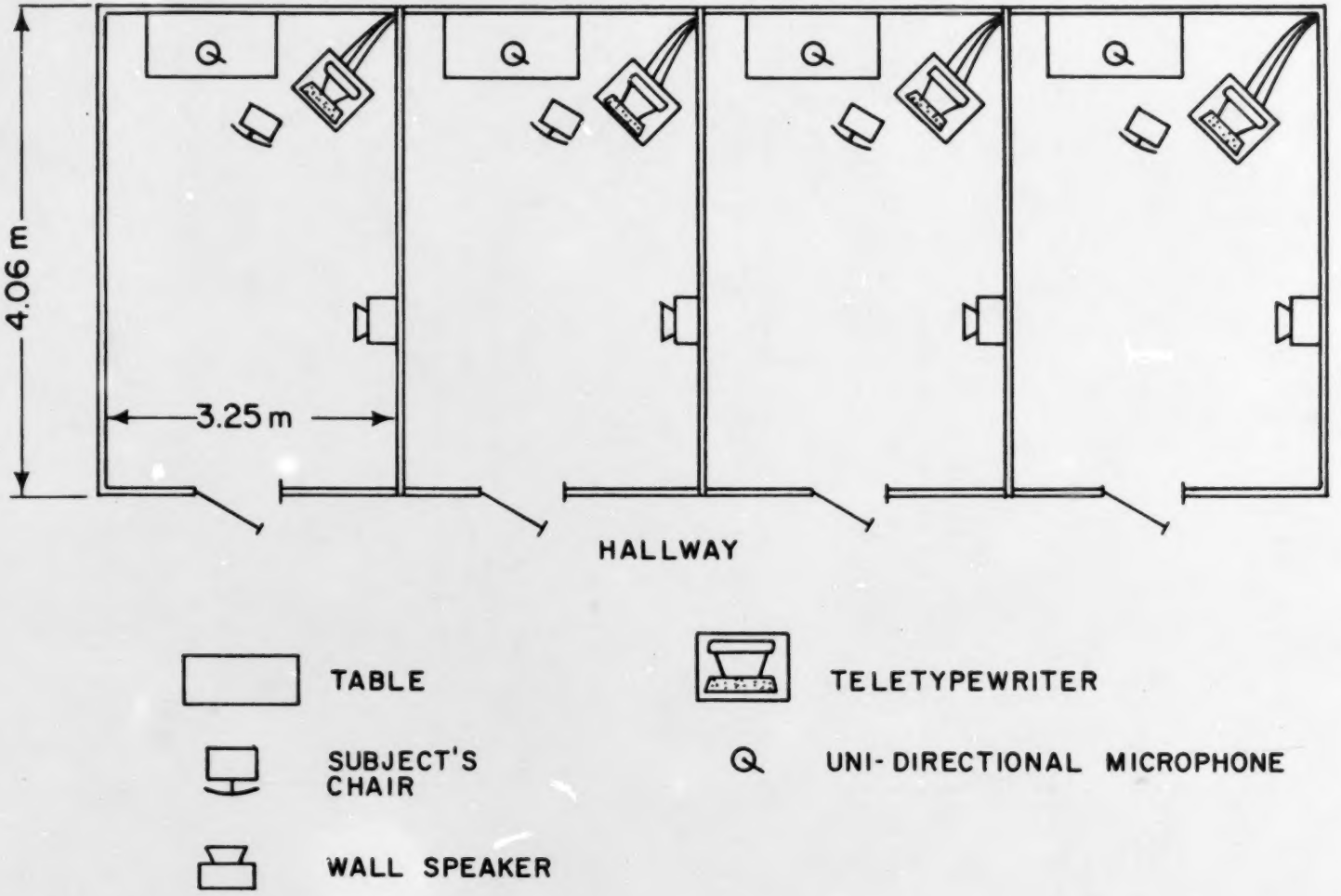

Figure 2. The four experimental rooms used in one of our experiments. (From Krueger, 1976)

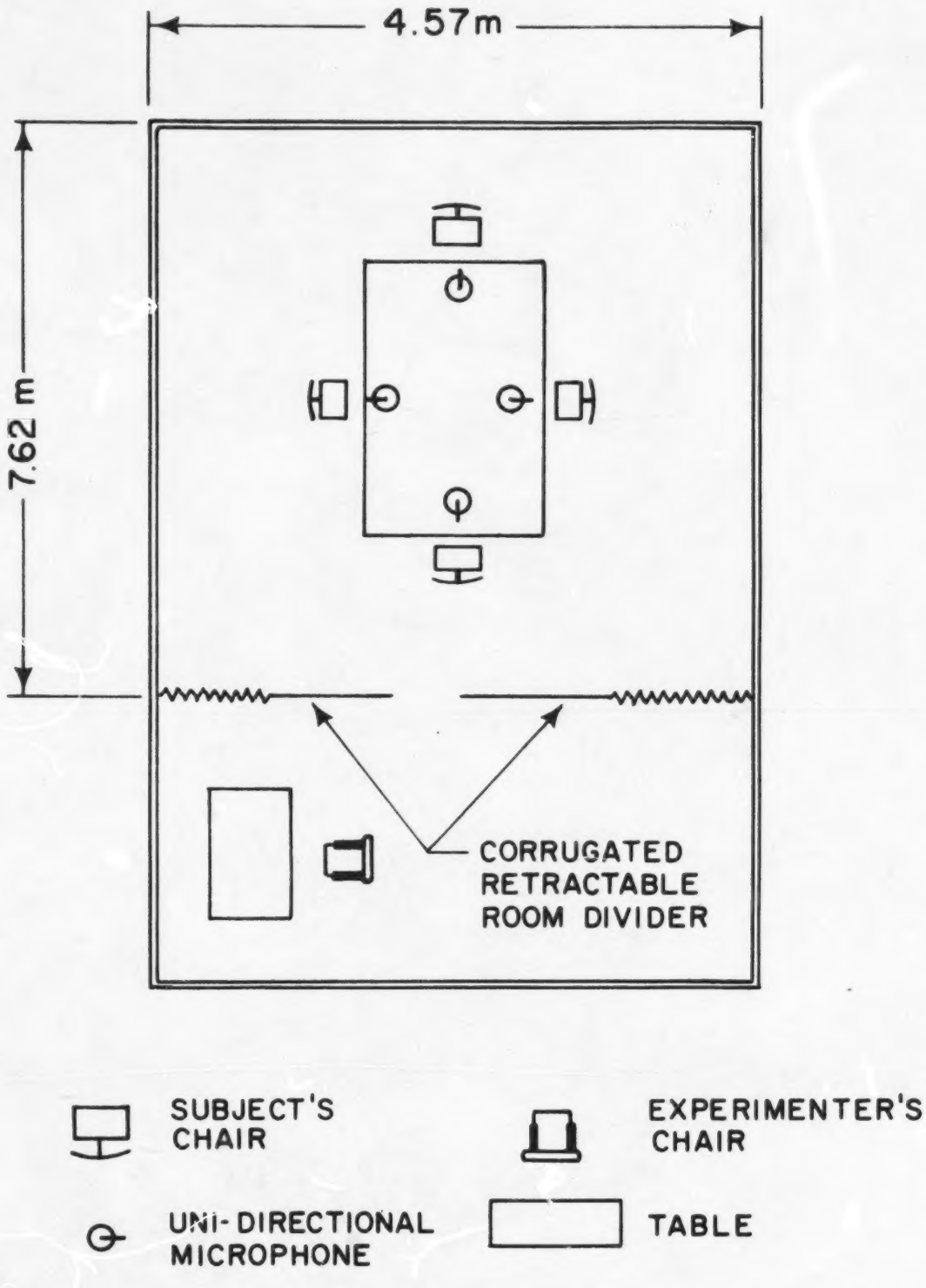

Figure 3. The conference room used in one of our experiments. (From Krueger, 1976)

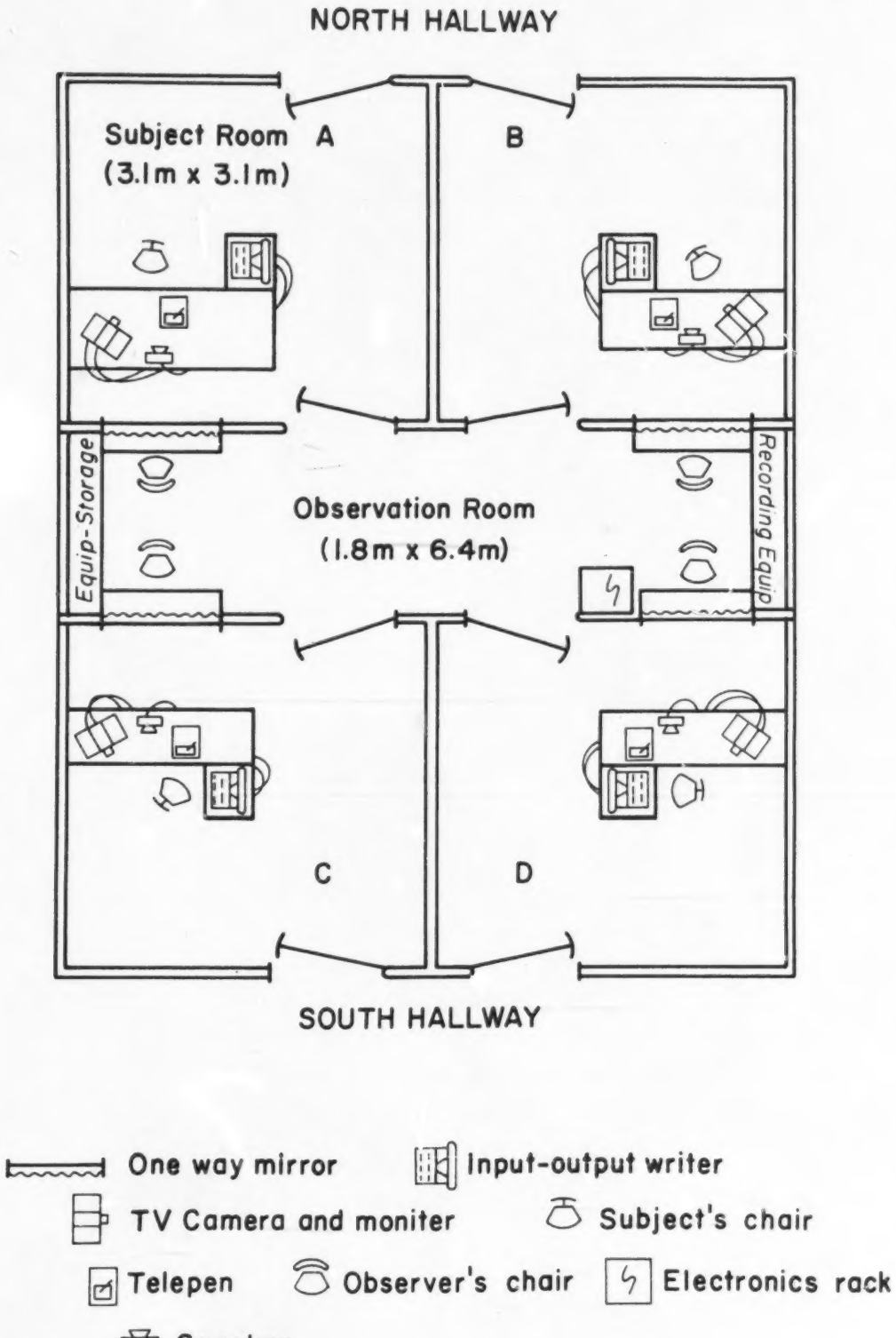

Figure 4. The new communication laboratory at Johns Hopkins.

(5) They require few or essentially no specialized skills or knowledge for their solution.

(6) They are formulated in such a way that their solutions require the efforts of two individuals working together as a team. This is done by deliberately structuring the problems so that each member of a team receives complementary information folios. One member of the team, the seeker, is given a problem for which he has to find a solution. His information folio consists of certain parts of the problem. The other member of the team, the source, has a folio with the remainder of the information needed to solve the problem. Therefore, while neither person can solve the problem by himself, the two of them have all the information necessary to do so.

The brief descriptions of seven of our cooperative problems below will convey some idea of their content, diversity, and flavor.

Class scheduling problem. The seeker is given a list of four college courses which have to be arranged into a workable schedule within specified time constraints, such as commuting schedules. The source has a 97-page booklet listing the complete time schedule for courses at the University of Maryland. The courses and constraints are such that there is only a single correct solution.

Information retrieval problem. The seeker's task in this problem is to prepare a bibliography of newspaper articles relevant to a particular topic, for example, the threat to individual privacy that would be posed by a United States Data Center based on a computerized information retrieval system. The source is given the *New York Times Index* for 1967, from which the citations are obtained to compile the bibliography.

Part identification problem. In this problem, the seeker is given a small pilot light socket (Figure 5), and is told to imagine that it is defective. His task is to obtain an identical replacement socket from the source. The source's information folio consists of an inventory of 65 pilot light sockets (Figure 6). Although all 65 are similar in many ways, each differs from all the others in one or more respects, e.g., in the kind of base (bayonet vs. screw), size (3/8 in. vs. 1/2 in. vs. 3/4 in.), and material (metal vs. bakelite). One and only one socket in the source's inventory matches the seeker's. The seeker is initially unaware of the extent or diversity of the source's inventory and so the two participants must exchange information in order to discover the

Figure 5. The electric light socket given the seeker at the start of the object identification problem.

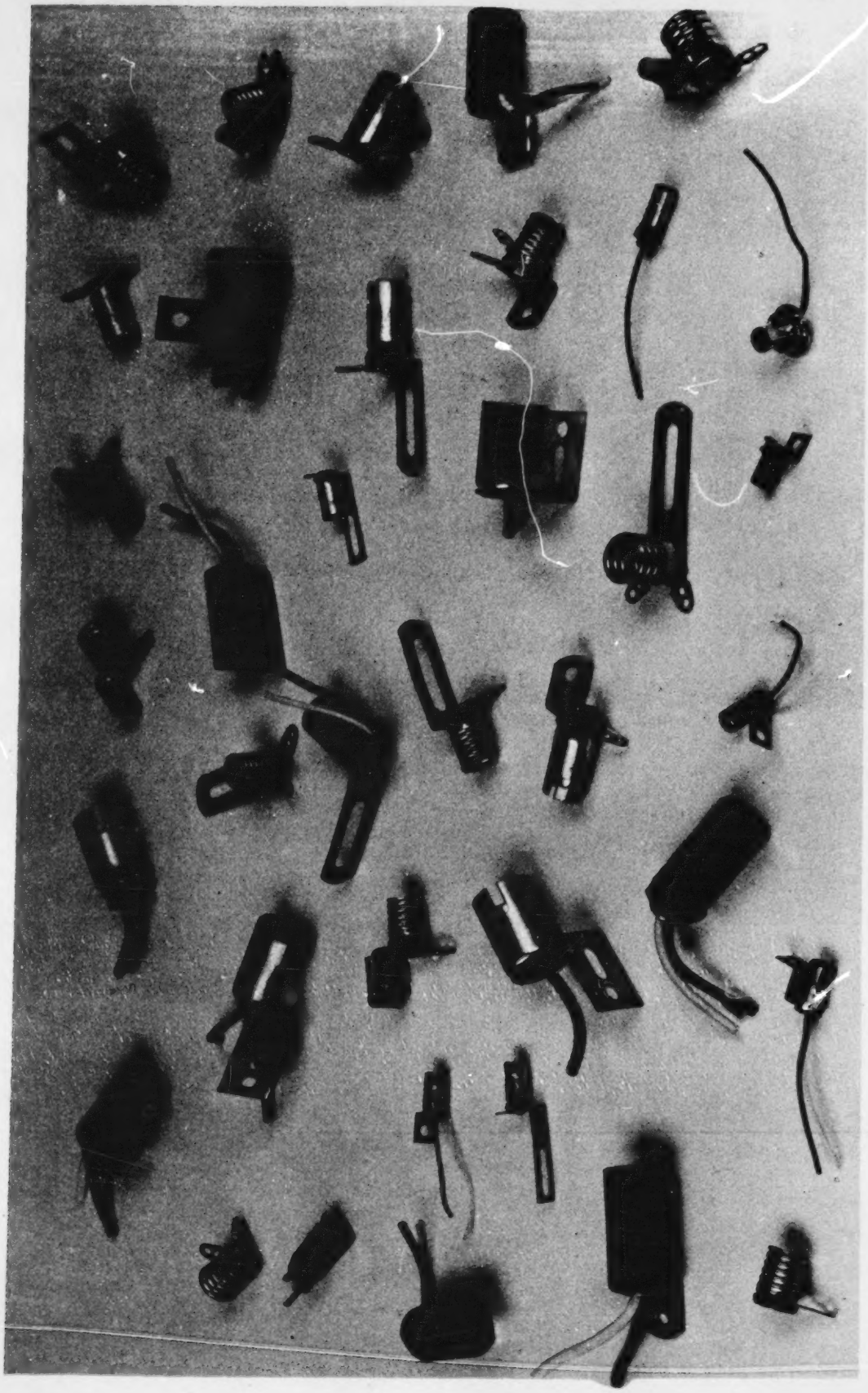

Figure 6. The set of light sockets given the source at the start of the object identification problem.

relevant features. The problem is complete when the seeker has the replacement socket in his possession.

Fault-finding problem. The seeker in this problem has to test a mock-up of an automobile ignition system using a commercially available auto analyzer. The mock-up of the ignition system is constructed of genuine automobile parts. The source has a booklet with a description of the auto analyzer and detailed instructions for using the analyzer in making a variety of tests. The problem is completed when the seeker, with the aid of information supplied by the source, has performed all the necessary tests and has identified the defects that are built into the mock-up.

Catalog ordering problem. The seeker's task in this problem is to select furniture with which to furnish an office. He is given a sum of money and is told to spend as much of it as possible in purchasing the five specified items: a desk, chair, file cabinet, waste basket, and bookcase. The source is given a mail order catalog which contains various selections of these items. To insure a unique solution, certain items in the catalog are marked "out of stock" or "discontinued."

Equipment-assembly problem. In this problem, the seeker's job is to assemble a common household article, a trash can carrier. His information folio consists of all the disassembled parts of that article, just as it is received from the catalog order house from which it was purchased. To provide easy access and identification, the parts are hung in a standard arrangement on a pegboard panel. Although the assembled device is large (approximately 61 X 91 X 122 cm in overall dimensions), it is constructed of light-weight aluminum tubular pieces that can be easily handled by a single person. A screwdriver, pair of pliers, and a mallet are provided. The source's information folio consists of a set of drawings and assembly instructions exactly as provided by the company from which the item had been purchased.

Geographic orientation problem. In this problem, the seeker's task is to find the office or residence address of a physician closest to a hypothetical home address in Washington, D.C. The home address had been carefully chosen so as to provide an unambiguous, unique solution to the problem. The seeker is supplied with an index of streets, a gridded street map of Washington, and a card on which the home address is typed. The home address is also marked on the map. The source is supplied with one page of physicians' listings from the classified advertising (yellow) pages of the Washington, D.C. telephone directory.

Conflictive Problems

Our conflictive problems are structured to provide a setting for argumentative discourse among communicators. The topical matter for discussion is chosen to be relevant to the subject population, yet is sufficiently general in nature that none of the participants is likely to have an inherent advantage by virtue of specialized experience. The problems are also designed to be used, and they have been used, with groups of more than two persons. Since there are no unique solutions to the problems, the subjects are left to debate the merits of alternative solutions in meeting certain criteria, and are required to arrive at a consensus or agreement. An example of each of two different kinds of conflictive problem follows:

National issues problem. The participants are asked to rank order the ten most important issues facing the United States today. An additional requirement is that the participants must rank order the issues, not as they think about them privately, but as they think the average undergraduate student had ranked them in a prior survey. The purposes of the latter requirement are to provide (a) an additional basis for argumentation, and (b) a basis for estimating the "goodness" of the solutions.

Budget-negotiation problem. We have several variations of a budget-negotiation problem. The following describes one that seems to generate a considerable amount of interest among our undergraduate students. The subjects are told that the University's Director of Athletics must reduce expenses in a number of different areas of expenditure, for example, uniforms and equipment, athletic scholarships, and travel. The subjects are cast in the role of captains of various teams, for example, football and lacrosse, and they have to agree on the areas in which budget cuts will be made. The payoffs for the different subjects are different so that a cut in expenditure for transportation for the football team is not equivalent to that for the lacrosse team. Each subject knows his own payoff structure but not that of the other participants. Each subject's goal is to minimize the losses to his side, that is, his team, and each subject's payment for participation in the experiment is reduced in proportion to the losses he sustains from the mutually-agreed upon solution to the problem.

OTHER EXPERIMENTAL CONDITIONS

Without elaborating in detail, our experiments have been done on three different populations:

High school boys, high school girls, and college students at Johns Hopkins. In some cases, subjects have been selected for particular intellectual abilities.

Most of our experiments have been done with two participants. One, however, has been done with as many as four subjects. All our experiments have tested at least two different problems. In four experiments, subjects have been tested on as many as four successive days.

RESULTS

Our results have been so numerous that it is impossible to summarize them all here. Rather I shall discuss some of the more salient findings, particularly as they seem to bear on the problem of telecommunication.

Communication by Voice is Fast

One of the strongest generalizations emerging from our research is that:

1. *Problems are solved significantly faster in communication modes that have a voice channel than in those that do not.*

This finding is a consistent one that has come up in every one of the six experiments in which this comparison was tested (Chapanis et al., 1972; Chapanis & Overbey, 1974; Krueger, 1976; Ochsman & Chapanis, 1974; Weeks & Chapanis, 1976; and Weeks et al., 1974). Data from the first experiment in which this finding appeared are shown in Figure 7 (See also Figures 9 and 10). Even more interesting are the data in Figure 8 which compared 10 different communication modes. There is only one statistically significant effect for the data in Figure 8. The five modes on the left are significantly faster than the five on the right. The one thing that distinguishes the two groups is that the five modes on the left all have a voice channel. Those on the right do not.

The finding that people can talk faster than they can write or typewrite, and so can solve problems faster when they can talk, is not in itself particularly startling. However, these findings become more interesting when they are elaborated in the light of others below.

Face-to-Face Versus Voice Communication

A second strong generalization is that:

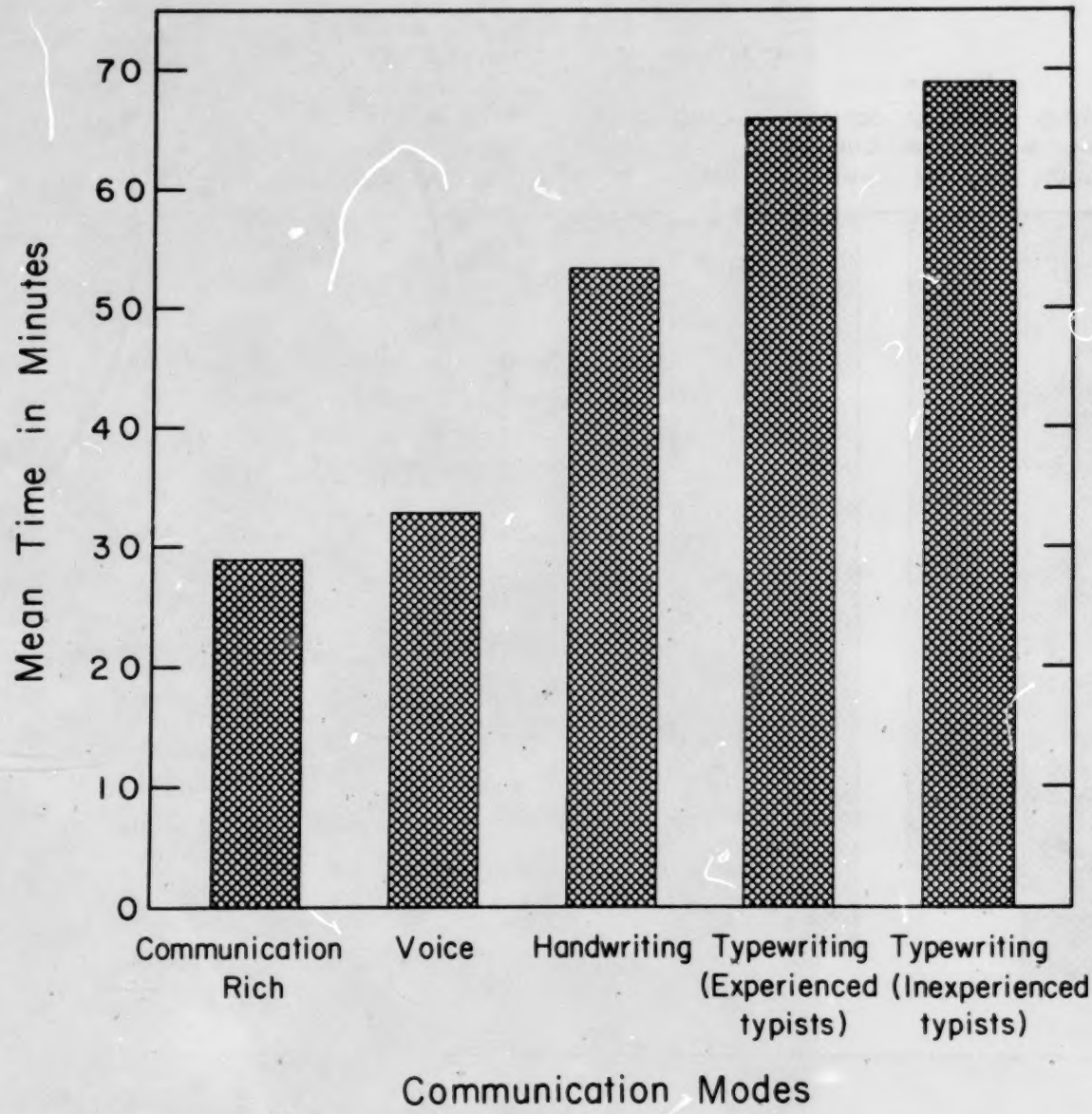

Figure 7. Mean time to solve problems in four different communication modes. Each bar is an average for four two-man groups and for two different problems. (From Chapanis et al., 1972)

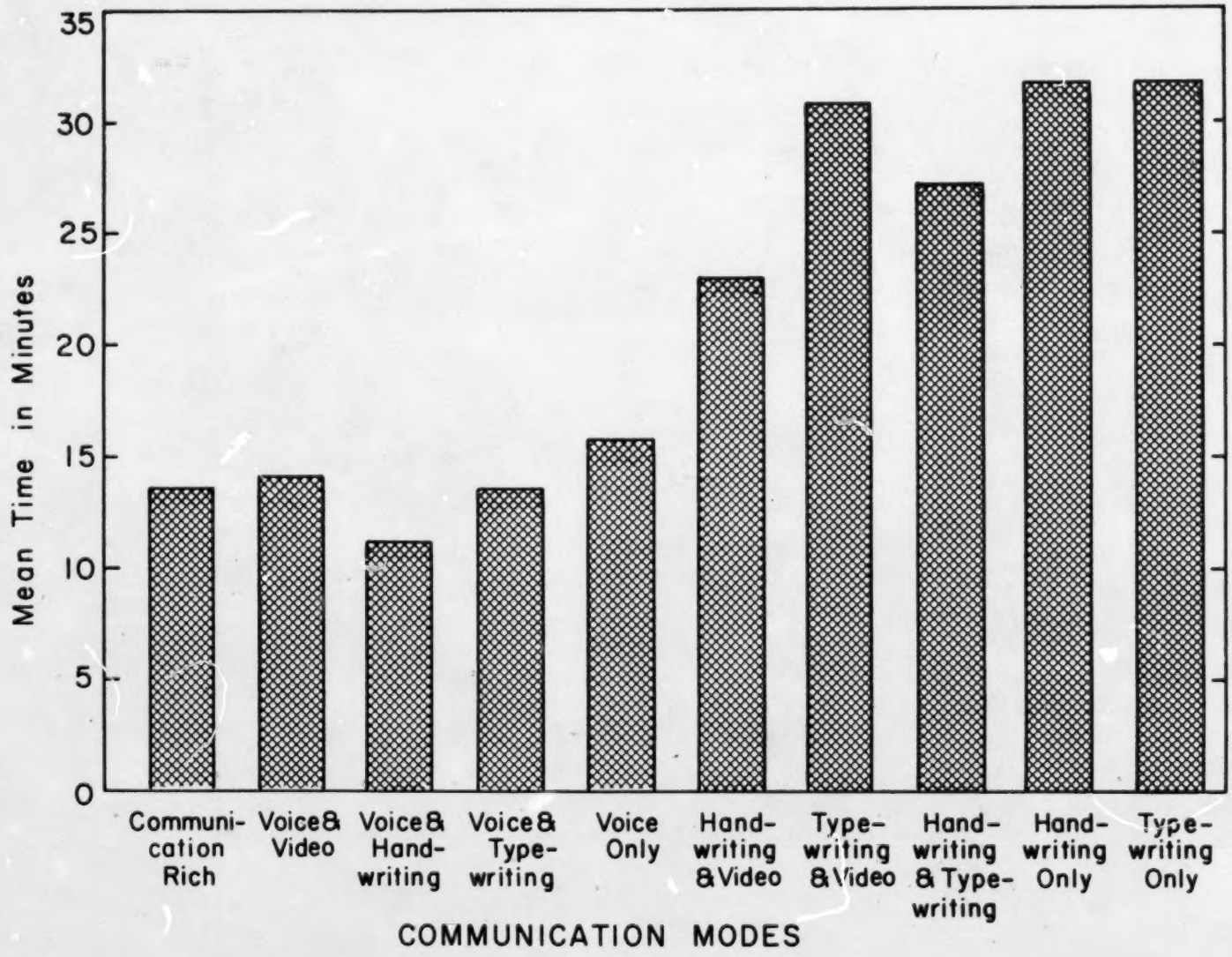

Figure 8. Mean times to solve problems in ten different communication modes. Each bar is an average for six two-man groups and for three different problems. (From Ochsman & Chapanis, 1974)

2. *Both cooperative and conflictive problems are solved about equally fast in voice-only modes of communication as in face-to-face communication.*

This finding came as a surprise to us initially but we have found it in no less than four different experiments (Chapanis et al., 1972; Krueger, 1976; Ochsman & Chapanis, 1974; and Weeks & Chapanis, 1976). The data in Figures 7 and 8 show that the voice-only modes of communication are a little slower than face-to-face communication in those two experiments. In neither case, however, is the difference statistically significant. In one very large experiment, the data came out the reverse, that is, voice only was faster than face-to-face communication (Figure 9). Once again, however, this particular difference is not statistically significant. Contrary to what one might expect, being able to see the person(s) with whom one is communicating does not appear to be of any substantial advantage in solving the kinds of problems we have tested.

Skilled Versus Unskilled Typists

Of particular interest to computer conferencing and to man-computer interactions is that:

3. *Typing skill does not appear to be a significant factor in the kind of communication with which we are concerned.*

This finding appeared in our first experiment (Figure 7) in which we tested a group of high-school boys who had completed a one-year course in typing and another group without any formal typing education. As is apparent from Figure 7 the difference between the performance of the two groups was trivial. This finding was so unexpected that we tested it in another more elaborate experiment with a completely different set of subjects (Weeks et al., 1974). The essential findings of that experiment are shown in Figure 10. The skilled typists solved problems about nine minutes faster than did the unskilled typists in the typewriting mode. However, the skilled typists were very nearly that much faster than their unskilled counterparts in the communication-rich (face-to-face) mode as well. So, although the skilled typists seem to have been able to solve these problems somewhat faster, there is no evidence whatsoever in these data that typing skill per se gave the skilled typists any differential advantage.

The apparently counterintuitive finding that typing skill does not significantly aid interactive communication via typewriters can be explained by three additional considerations: (a) Activity sampling

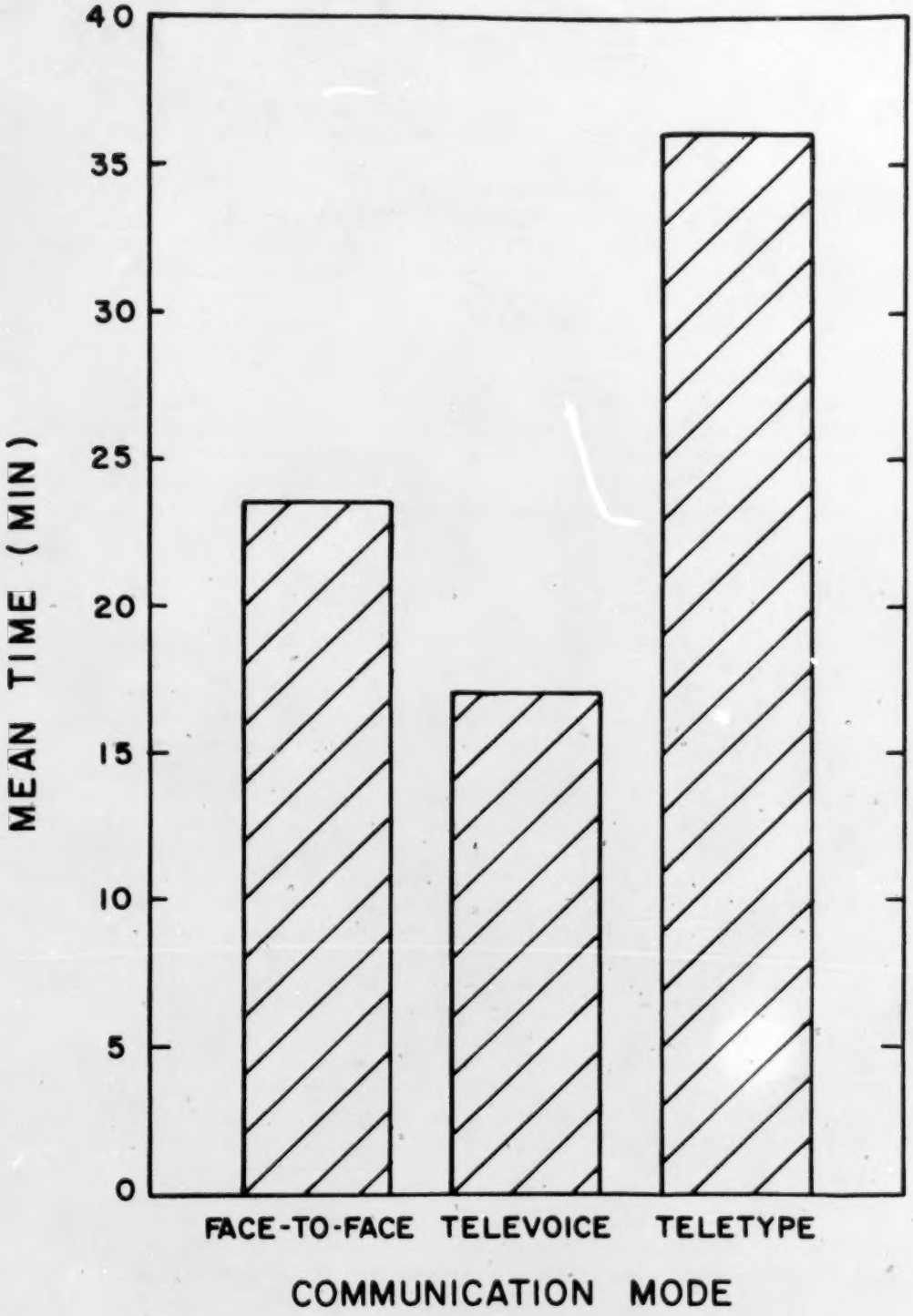

Figure 9. Mean times to arrive at consensus agreements in three communication modes. Each bar is an average for three groups, each of which worked at a different task on each of three successive days. Each set of three groups was made up of a 2-person, a 3-person, and a 4-person group. (From Krueger, 1976)

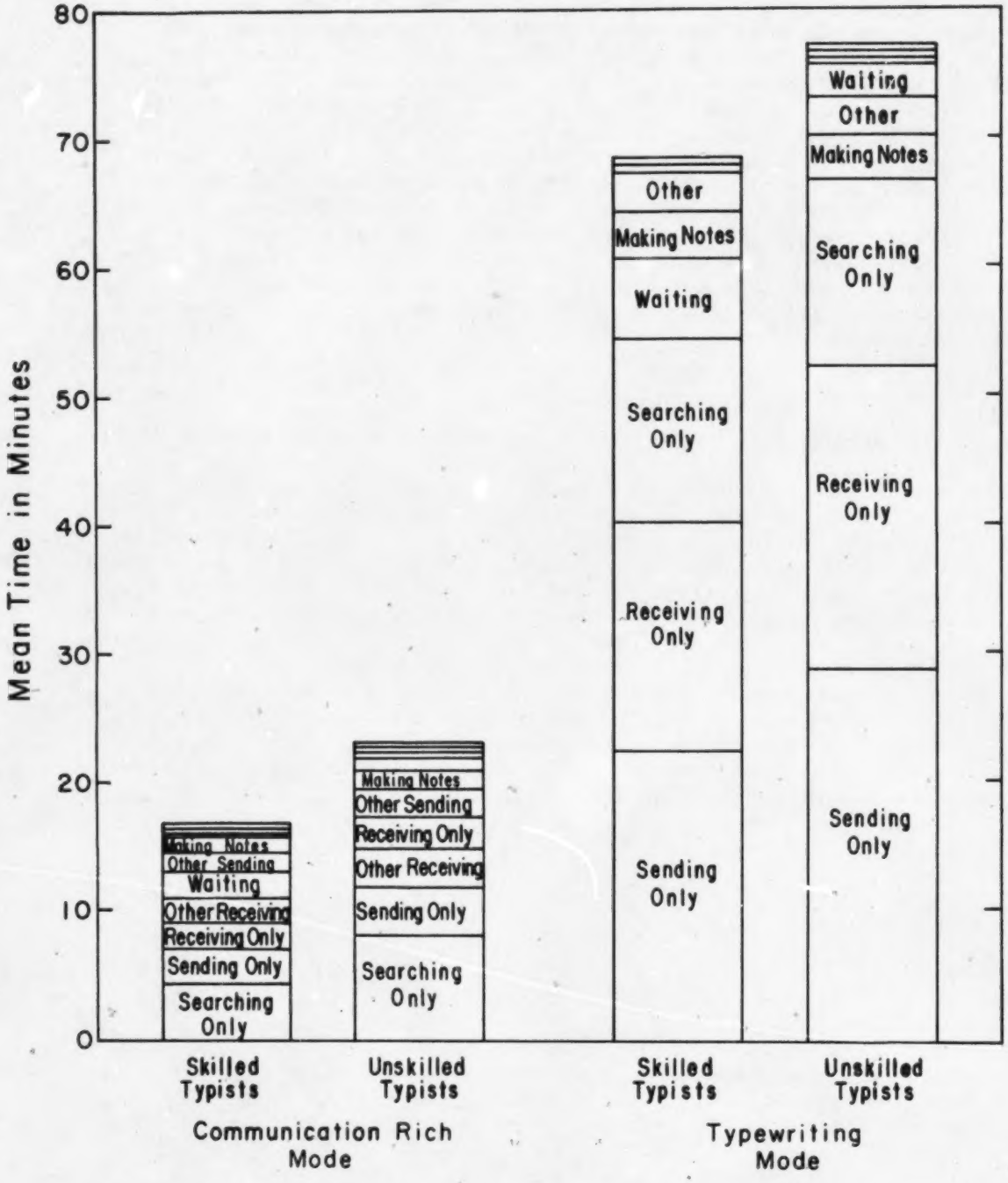

Figure 10. Mean times to solve problems by pairs of skilled and unskilled typists each of which solved problems in two communication modes. Each bar is an average for four groups each of which solved a different problem on each of two different days. The segments of the bars show the average amounts of time subjects spent in each of nine activities. (From Weeks, Kelly & Chapanis, 1974)

data on how subjects actually spent their time (Figures 10 and 11) show that only about one-third of the total problem-solving time is spent in sending, that is, in typing. This means that any potential advantage a subject might have due to typing skill would be operating only one-third of the time. (b) Typing skill is normally measured by the speed and accuracy with which typists copy prepared text. These communication situations, by contrast, require a great deal of planning and decision-making as subjects decide what to say and then compose their messages at the typewriter. Typing skill does not have very much to do with that kind of planning and decision-making. (c) Normal human communication is naturally full of all kinds of errors and human communicators are quite adept at reading through those errors. Accurately typed material is not very important for normal interactive communication.

Verbal Output

Another strong finding from a number of our experiments is that:

4. *Modes of communication that have a voice channel are much wordier than those that do not have a voice channel.*

This generalization holds no matter how one measures wordiness, or verbal output. Figure 12 shows the number of words communicated in the four modes tested in our first experiment. These data match those in the same experiment for which Figure 7 gives times to solution. Considering that problems are solved about twice as fast in the voice modes as in the hard-copy (handwriting and typewriting) modes, the data in Figure 12 become all the more impressive (See also Figure 14). Figure 13 shows communication rates from the same experiment. These were computed by dividing the number of words used by each subject by the actual amount of time he spent communicating.

Face-to-Face Communication Versus Communication by Voice Only

A small, but consistent finding that has turned up repeatedly in our work is that:

5. *Face-to-face communication is wordier than communication by voice only.*

Data for this generalization appear in Figures 12 and 13. The differences between the communication-rich (face-to-face) and voice only data in these two figures are not statistically significant and one might be inclined, therefore, to attribute them to chance variations. However,

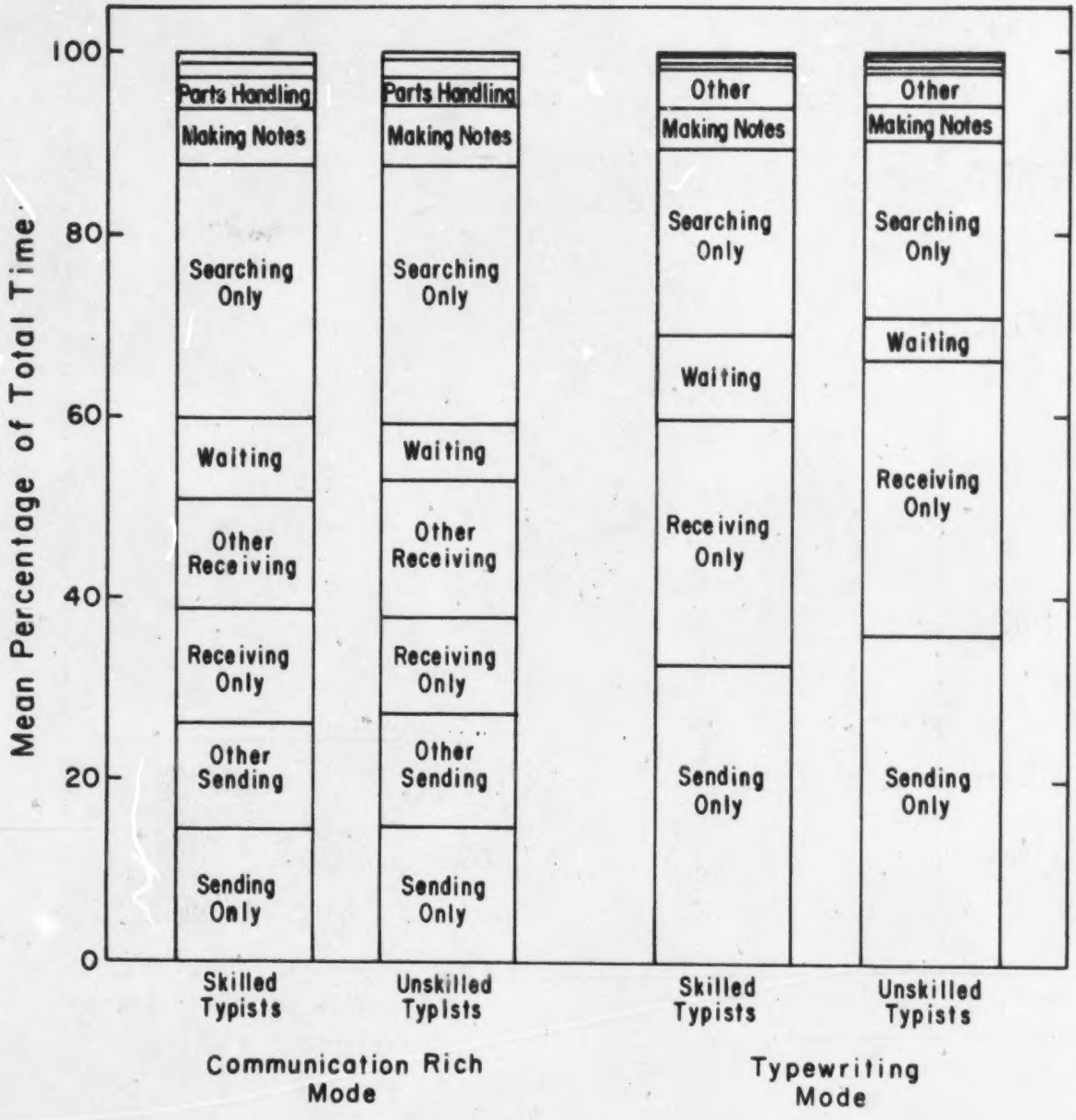

Figure 11. The data of Figure 10 are here replotted as percentages of the total time. (From Weeks et al., 1974)

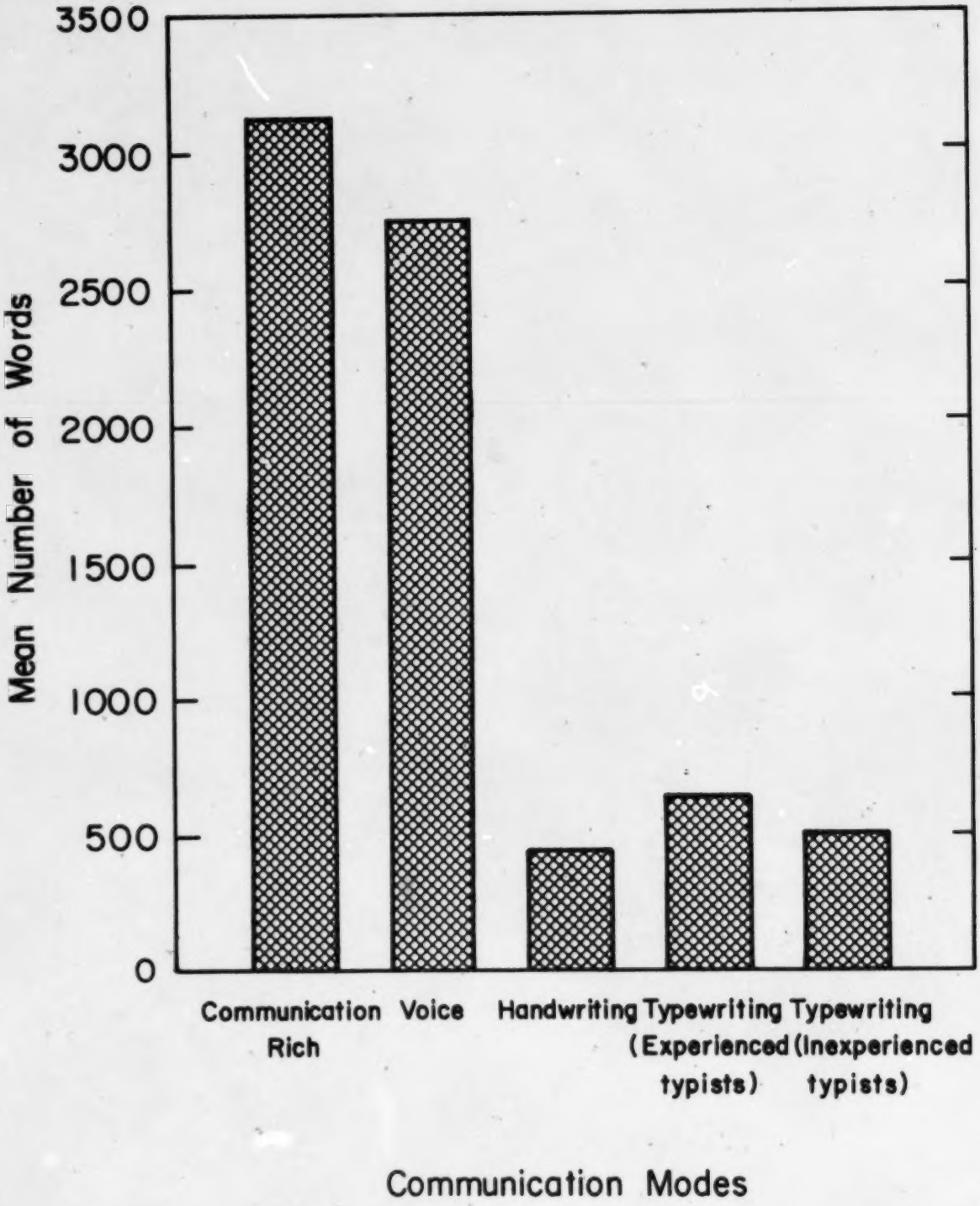

Figure 12. Mean number of words used in the solution of problems in each of four communication modes. These data and those in Figure 7 are from the same experiment. (From Chapanis et al., 1972)

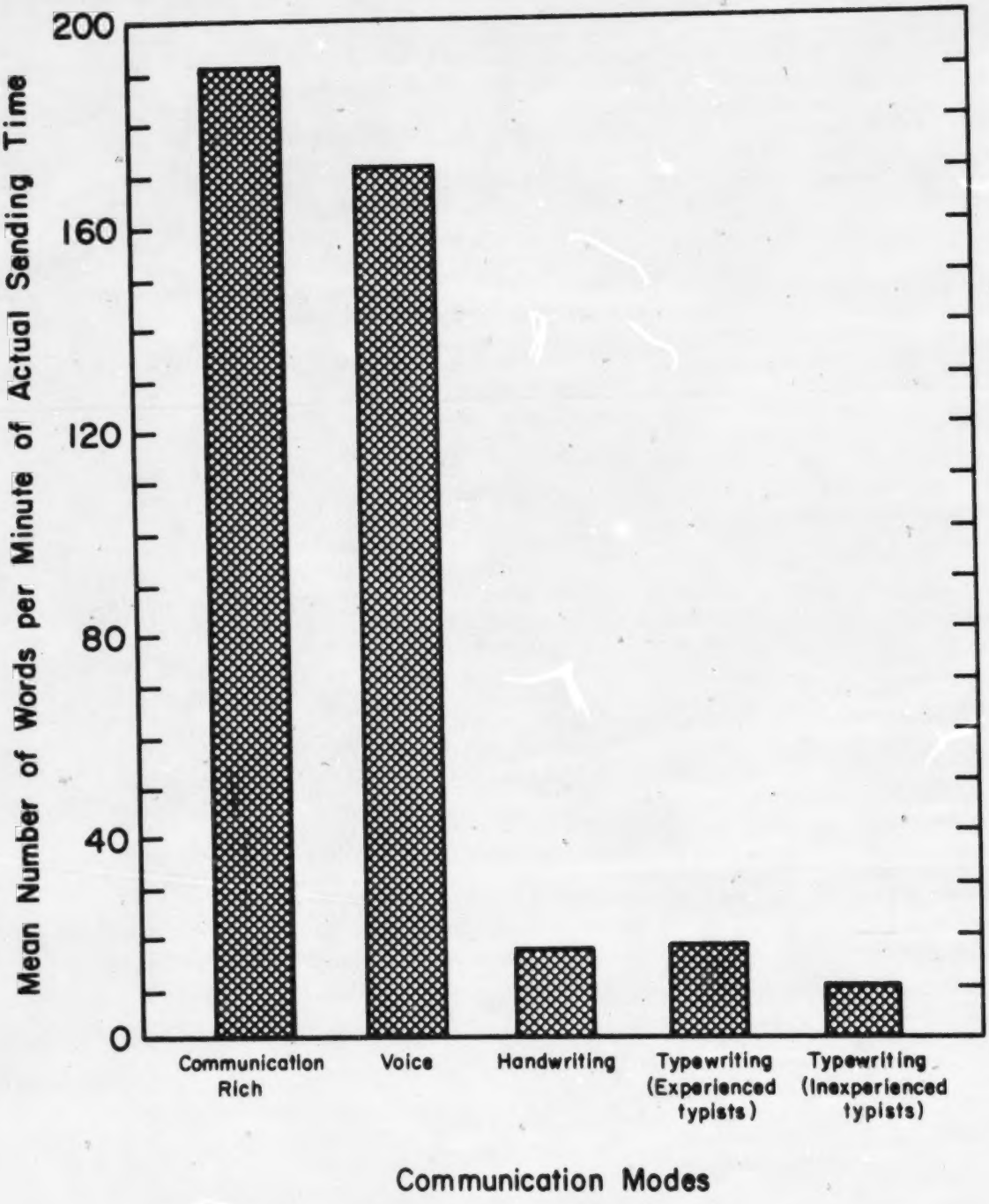

Figure 13. Communication rates in the solution of problems in each of four communication modes. These data and those in Figures 7 and 12 are from the same experiment. (From Chapanis et al., 1972)

the finding has turned up in all four experiments in which there has been a comparison of the verbal output in face-to-face and voice only modes. Figure 14, for example, shows another and much greater difference than we found in our earlier work. Being able to gesture and use body movements to convey information actually seems to increase the number of words communicators use.

Verbal Output Independent of Mode of Communication

An interesting finding that has turned up in our experiments bears on the stability of the verbal output in the several modes. It is:

6. *The number of words used by a communicator is a function of the communication channel and that number is not influenced by the channel available to his partner.*

Data supporting this statement are shown in Figure 15. The left-most pair of bars gives data for a situation in which both the seeker and source had a voice channel. The second pair of bars is for a condition in which the seeker had a voice channel, but the source could communicate only by typewriter. The third pair of bars is for the reverse situation: the seeker could communicate only by typewriter, while the source had a voice channel. The right-most pair of bars is for the condition in which both persons could communicate only by typewriter.

When both communicators had a voice channel (left-most pair of bars), the source used more words than did the seeker (See the filled bar). When the source had a voice channel and the seeker a typewriter channel (third pair of bars), the average number of words used by the source was almost identical to the number used by sources in the voice-voice condition. Similarly, the numbers of words used by seekers was almost identical when they communicated by voice, irrespective of whether the source had a voice channel or a typewriter channel (compare the open bars in the first and second pairs). Similar findings apply to the data for the typewriter channels. To sum up, the number of words used by a communicator is a function of the channel available to him and is not influenced by the channel available to his partner.

Interrupt Capability

In one experiment we tested the effects of giving communicators the freedom to interrupt their partners. The findings of that study support the conclusion that:

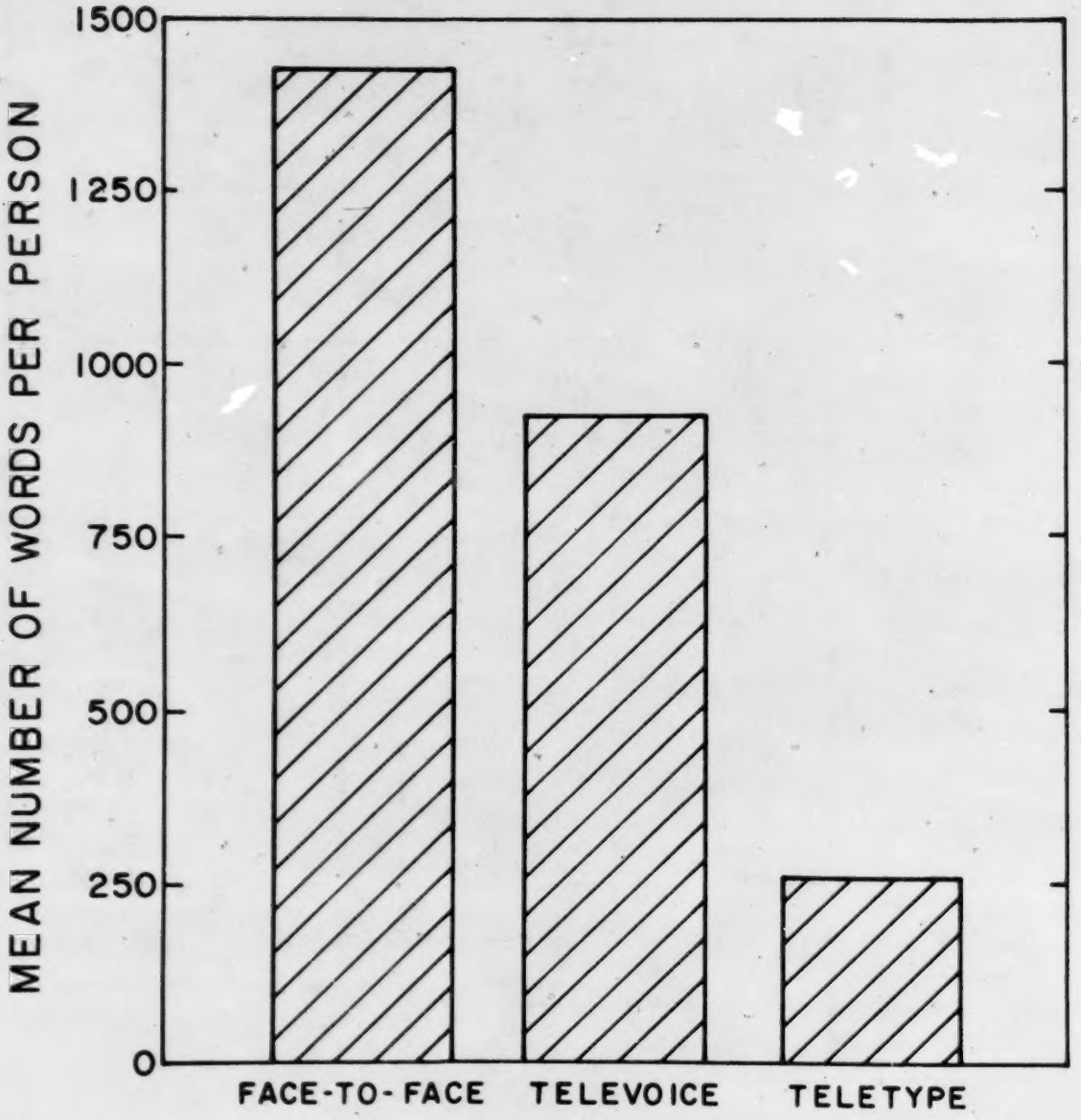

Figure 14. Average number of words used in arriving at consensus agreements in three communication modes. These data and those in Figure 9 are from the same experiment. (From Krueger, 1976)

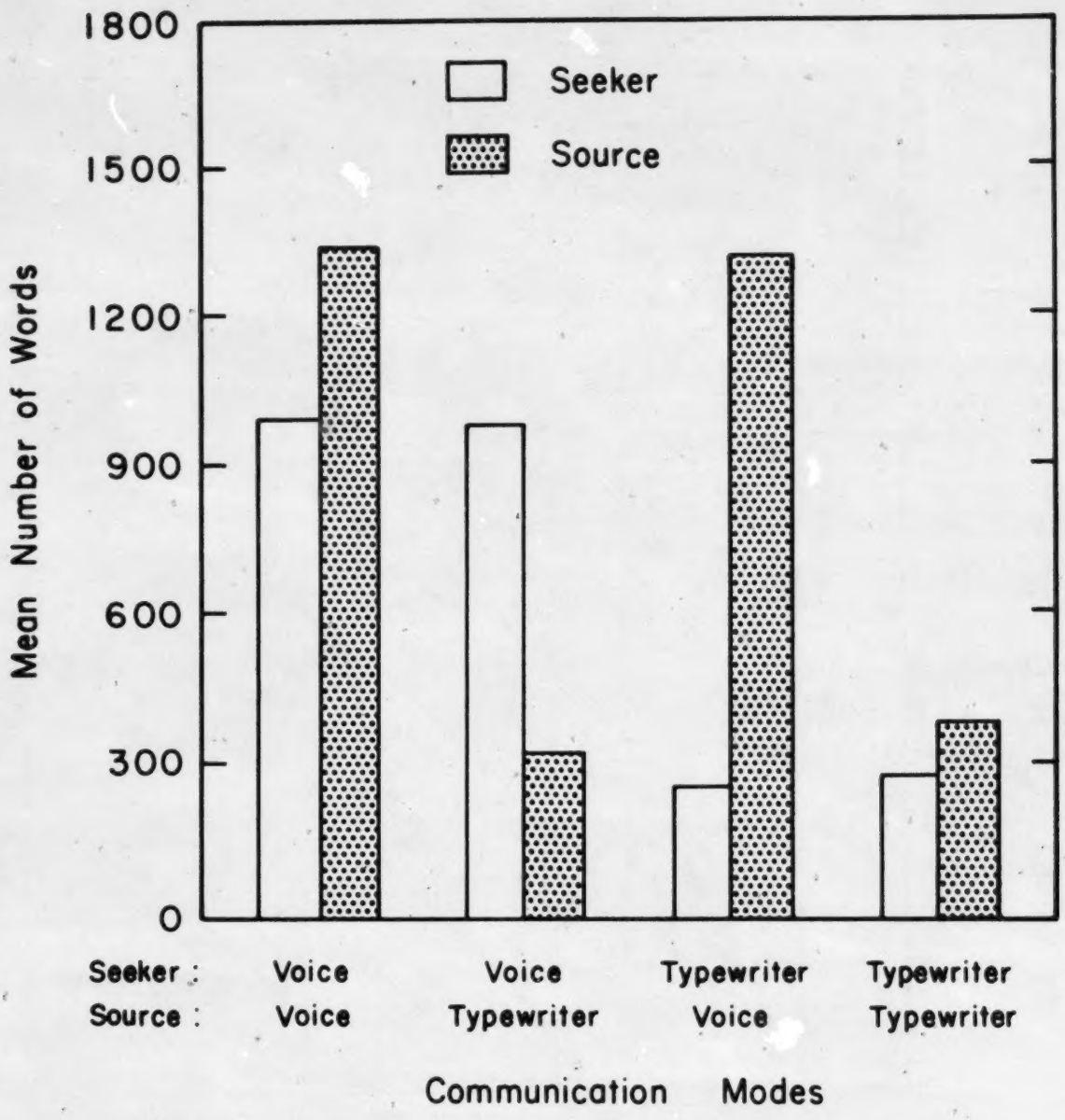

Figure 15. Mean number of words used by sources and seekers when two channels of communication were tested in all combinations. Each bar is the average for eight subjects, two each of whom solved one of four different problems on one of four different days. (From Chapanis & Overbey, 1974)

7. *Giving communicators the freedom to interrupt has no effect on problem solution time or on the number of words used. Words are, however, "packaged" differently. When communicators have the freedom to interrupt, they use more messages and messages are shorter. When communicators do not have the freedom to interrupt, they use fewer messages and messages are longer.*

Data supporting these conclusions are given in Figures 16 and 17. In the free interchange condition, a communicator could interrupt his partner at any time and take control of a voice channel, or a typewriter channel. In the restricted interchange condition, a communicator had to wait until his partner had finished talking, or typing, and had released the channel to him. The data in the two figures are almost mirror images of one another. When the two sets of data are multiplied together, they yield essentially equal numbers of words.

Control over Communication Channels

In one experiment we gave subjects two buttons. When a subject pressed one button, he relinquished control of the communication system to his partner. When a subject pushed the other button, he took control away from his partner, even if the partner was in the process of communicating. The findings of this experiment suggest that:

8. *Communicators are much more likely to take control of a communication system (that is, to interrupt) if the system has a voice channel. Subjects voluntarily relinquish control of a system about as often as they take control if the system has only hard-copy channels of communication.*

Data supporting this finding appear in Figure 18. Note that in every one of the five pairs of bars on the left, subjects took control of the communication system much more often than they relinquished control. All five of those communication systems have a voice channel. By contrast, the five pairs of bars on the right are about equally high. Those five pairs of bars are for communication modes that do not have a voice channel.

Time Spent in Various Activities

In seven of our experiments (Chapanis et al., 1972; Chapanis & Overbey, 1974; Kelly, 1976; Ochsman & Chapanis, 1974; Parrish, 1974; Weeks & Chapanis, 1976; Weeks et al., 1974) we used activity sampling

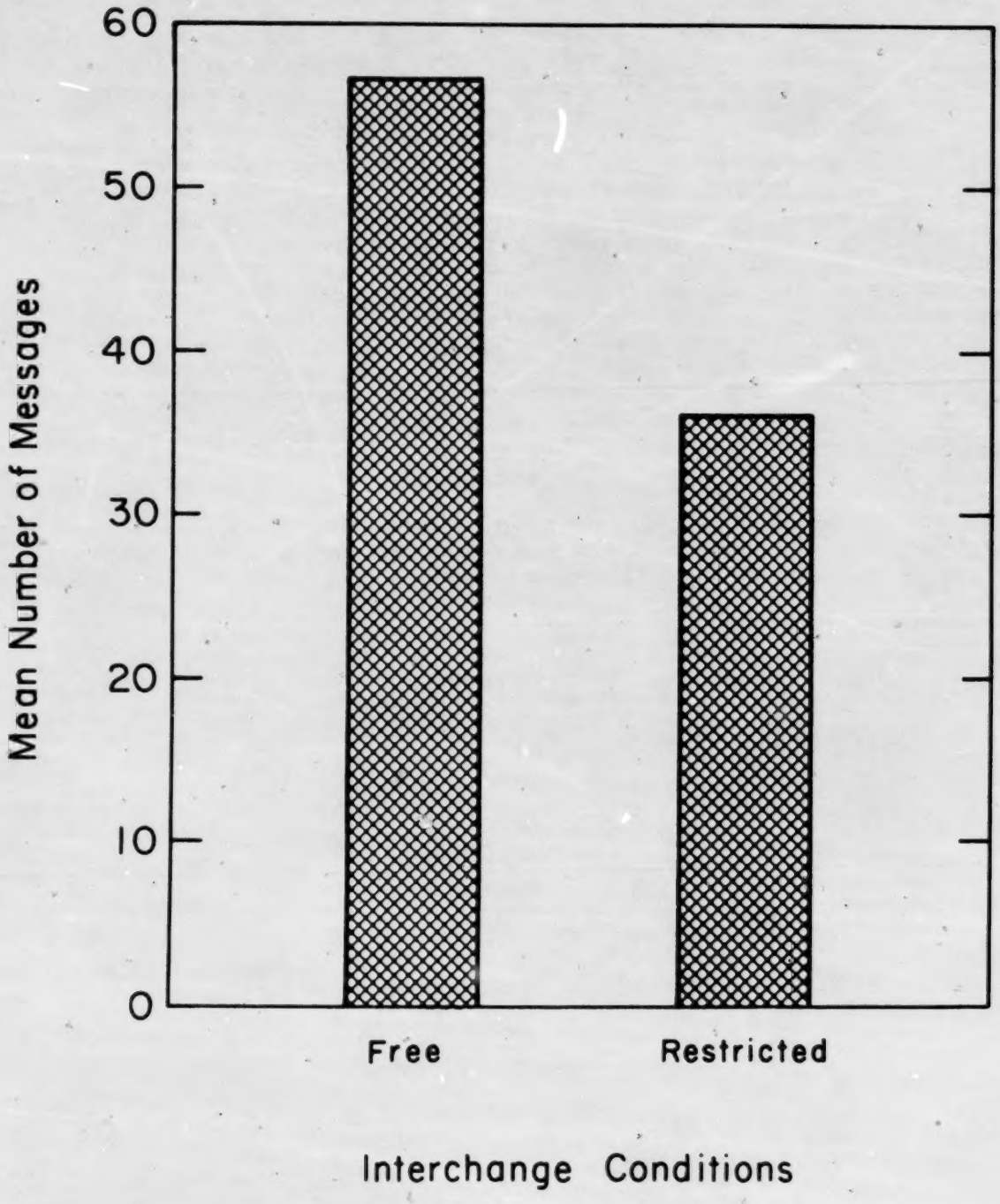

Figure 16. Mean numbers of messages exchanged under conditions of free and restricted interchange. Each bar is an average of 64 observations. Eight two-person teams each solved four different problems on four different days using each of the channel combinations illustrated in Figure 15. (Chapanis & Overbey, 1974)

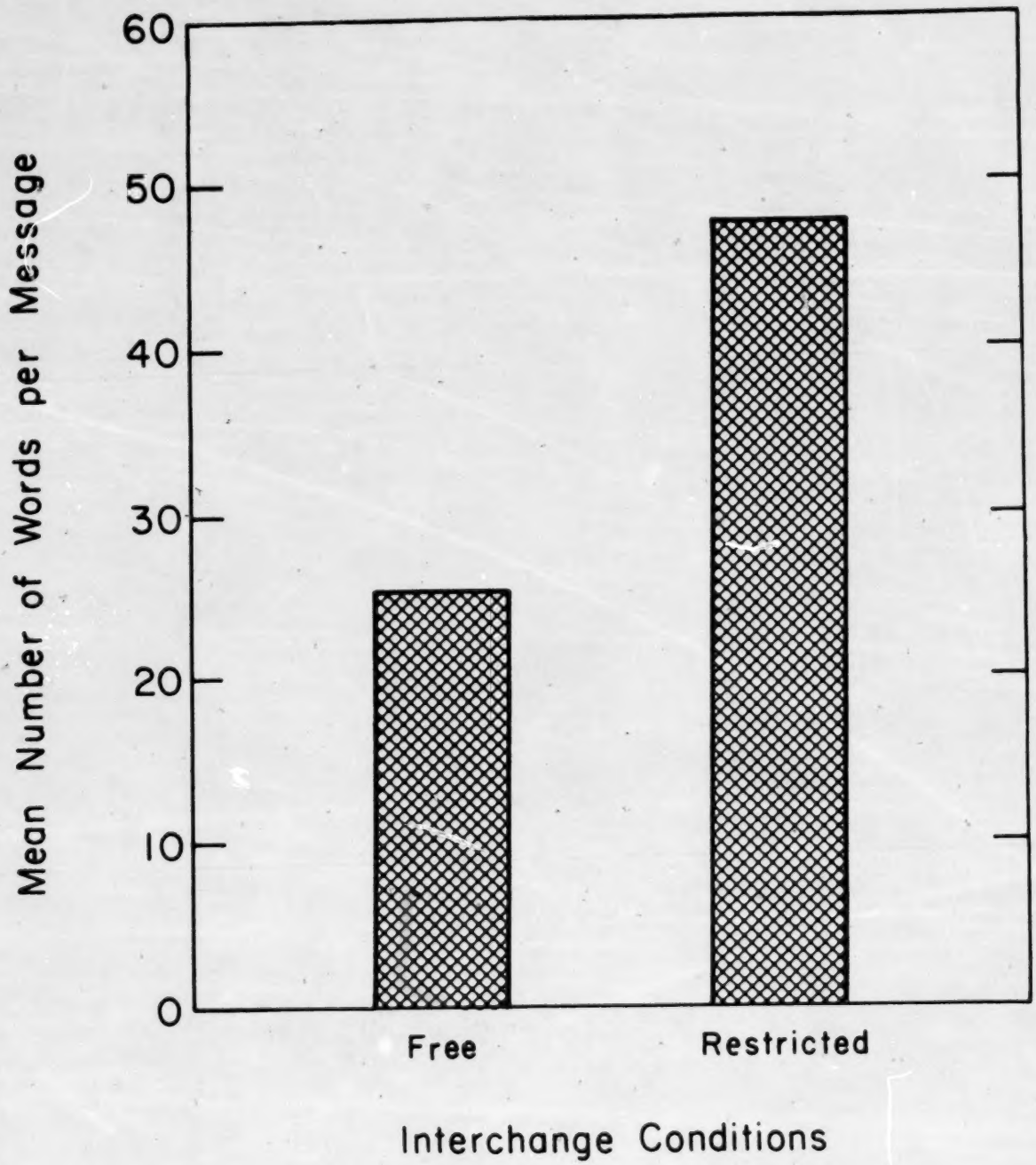

Figure 17. Mean message lengths for the same data as are shown in Figure 16. (From Chapanis & Overbey, 1974)

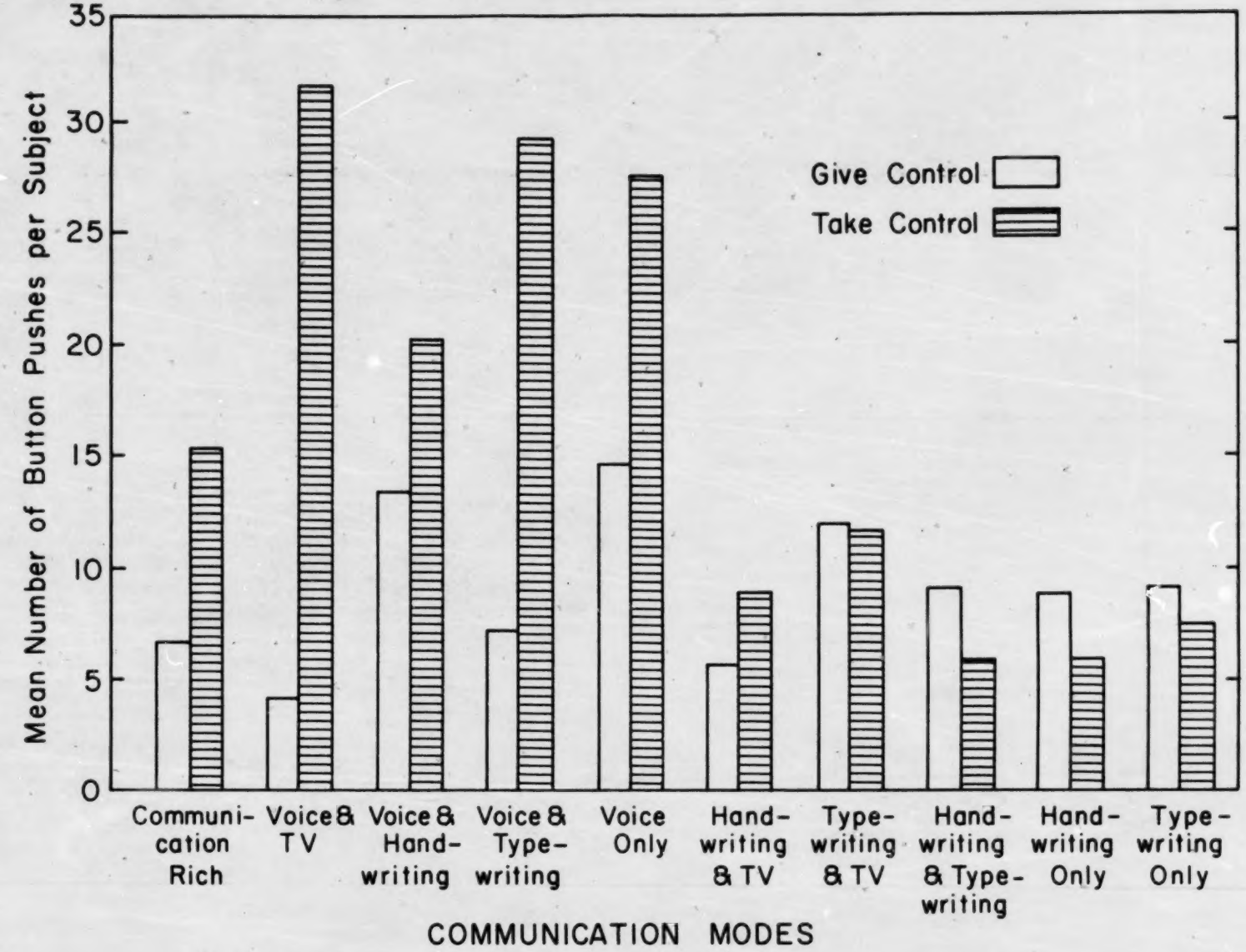

Figure 18. The mean number of times subjects gave and took control of communication channels. These data and those in Figure 8 are from the same experiment. Each bar here is based on 12 observations. (From Ochsman & Chapanis, 1974)

procedures to record what subjects were actually doing in the problem solving sessions. The findings of those experiments lead us to conclude that:

9. *In tasks requiring the exchange of factual information to solve problems, only about half a communicator's time is spent in actual communication, that is, in sending or receiving information. The rest of the time is spent in doing other things, for example, making notes, handling parts, or searching for information. When the task involves the exchange of opinions and argumentation, as much as 75 percent of a person's time may be spent communicating. However, at least 25 percent of a communicator's time is still spent in other activities, for example, making notes and searching for information.*

In our first experiment, we recorded behavior in each of 15 different categories. The data are shown in Figures 19 and 20. Perhaps the most impressive thing about both figures is that in four of the five bars the behavior consuming the largest single amount (or percentage) of time was something other than sending (that is, communicating). Only in the case of the inexperienced typists did sending take up the greatest amount , or percentage, of time. In this experiment, one problem solving task required subjects to assemble a trash can toter, the other to find a particular address on a street map of Washington, D.C. from telephone directory information. These are tasks requiring the use of pieces of equipment, or pieces of paper.

Our conflictive problems, for example, the national issue-ranking problem, are quite different in that there is no supplementary material required to arrive at agreement. Pieces of paper are typically used, however, to jot down notes. Mainly the communicators are required to voice their opinions and to argue the merits of their respective positions. Under these circumstances, the proportion of time spent communicating increases and it has gone as high as 75 percent. Even so, 25 percent or more of a typical communicator's time is spent in other activities, for example, making notes, searching for information, or waiting. Data to support these findings are not given here, but may be found in Weeks and Chapanis (1976).

Level of Sophistication of the Communicators

One of our experiments systematically varied the level of sophistication of the communicators (Parrish, 1974). The findings show that:

10. *The greater the level of sophistication of the communicators, the more quickly they are able to solve problems.*

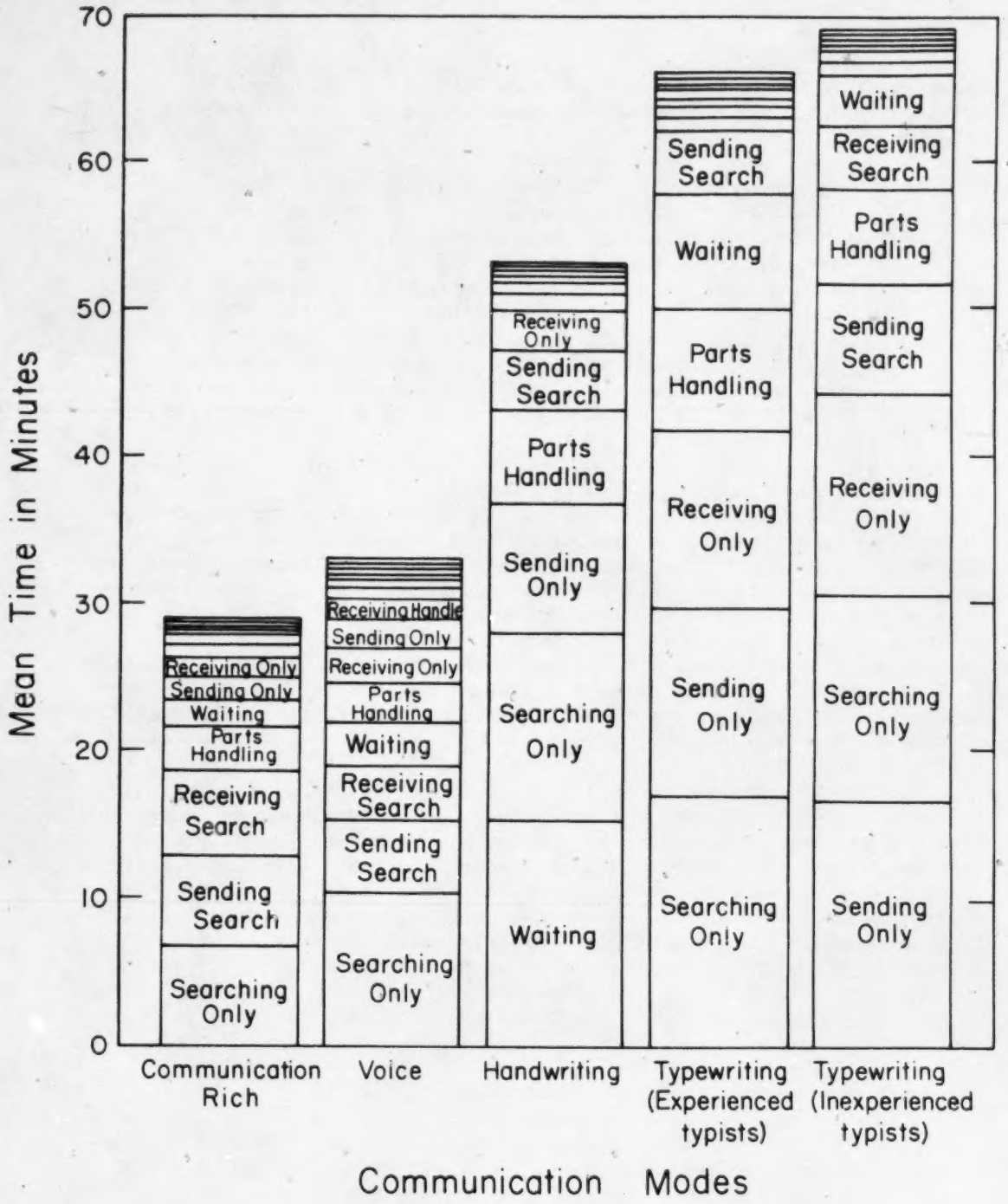

Figure 19. The data of Figure 7 are segmented here to show the amounts of time subjects spent in each of 15 different activities during problem-solving sessions. (From Chapanis et al., 1972)

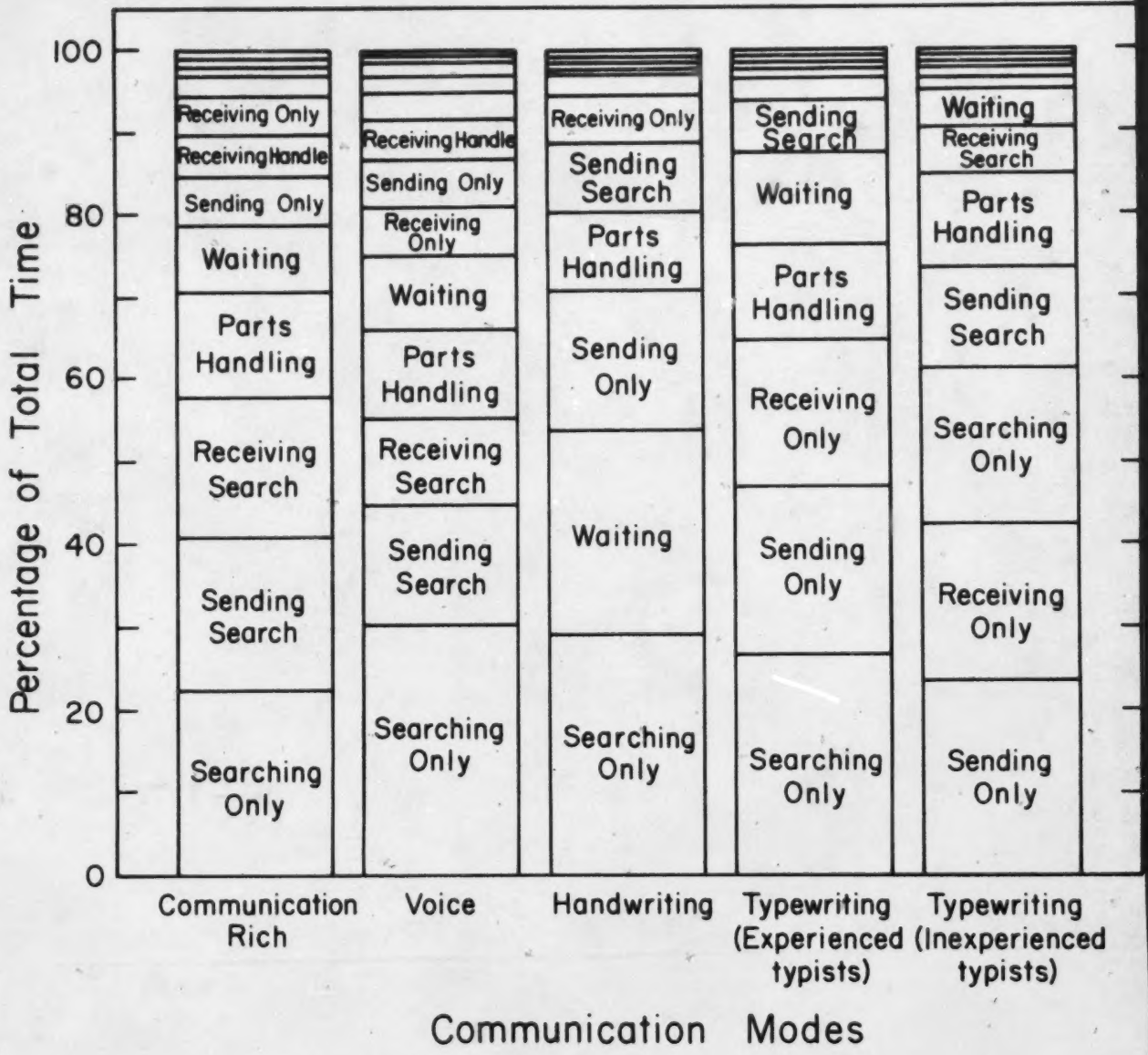

Figure 20. The data of Figure 19 are replotted here as percentages. (From Chapanis et al., 1972)

Data supporting this generalization appear in Figure 21. The teams here were made up of various combinations of high school and college students who served as seekers (SK) and sources (SO). College teams arrived at solutions fastest; high school teams slowest. When teams were mixed, it was better to have a college student as the source rather than as the seeker.

These findings can be explained by the greater facility college students have in using language. In our problems, the source was given the bulk of the library-like, or stored information. It was he who gave directions or instructions to the seeker about how to complete the problem at hand. This accounts for the faster performance of the mixed teams in which a college student served as source.

Even more interesting, perhaps, is the finding that:

11. *In these communication tasks, college students and high school students do about the same kinds of things, and in the same proportions. However, college students do everything faster.*

Data in support of this conclusion are given in Figure 22. The four bars in Figure 22 are so nearly alike that they seem to be traced from the same pattern!

Impersonality of the Communication Modes

It has been claimed that teletype or computer conferencing is more egalitarian and impersonal than face-to-face communication. We have some evidence for that claim from one of our experiments. The findings of that experiment suggest that:

12: *Communicators in teletype modes of communication are much more likely to share equally in the exchange of information than are communicators in face-to-face or voice only modes of communication.*

Data for that generalization are given in Figure 23. The mean relative variability (MRV) is based on a statistical measure called the coefficient of variation, MRV = CV = $100 \frac{\sigma}{M}$. In essence, this measure is an expression of the amount of variability (σ) among the various communicators in the numbers of messages they exchanged, when that variability has been compensated for the average number of messages (M). Larger numbers indicate greater disparity in the numbers of messages produced by the several communicators. Smaller numbers indicate that the several communicators shared more nearly equally in the production of messages.

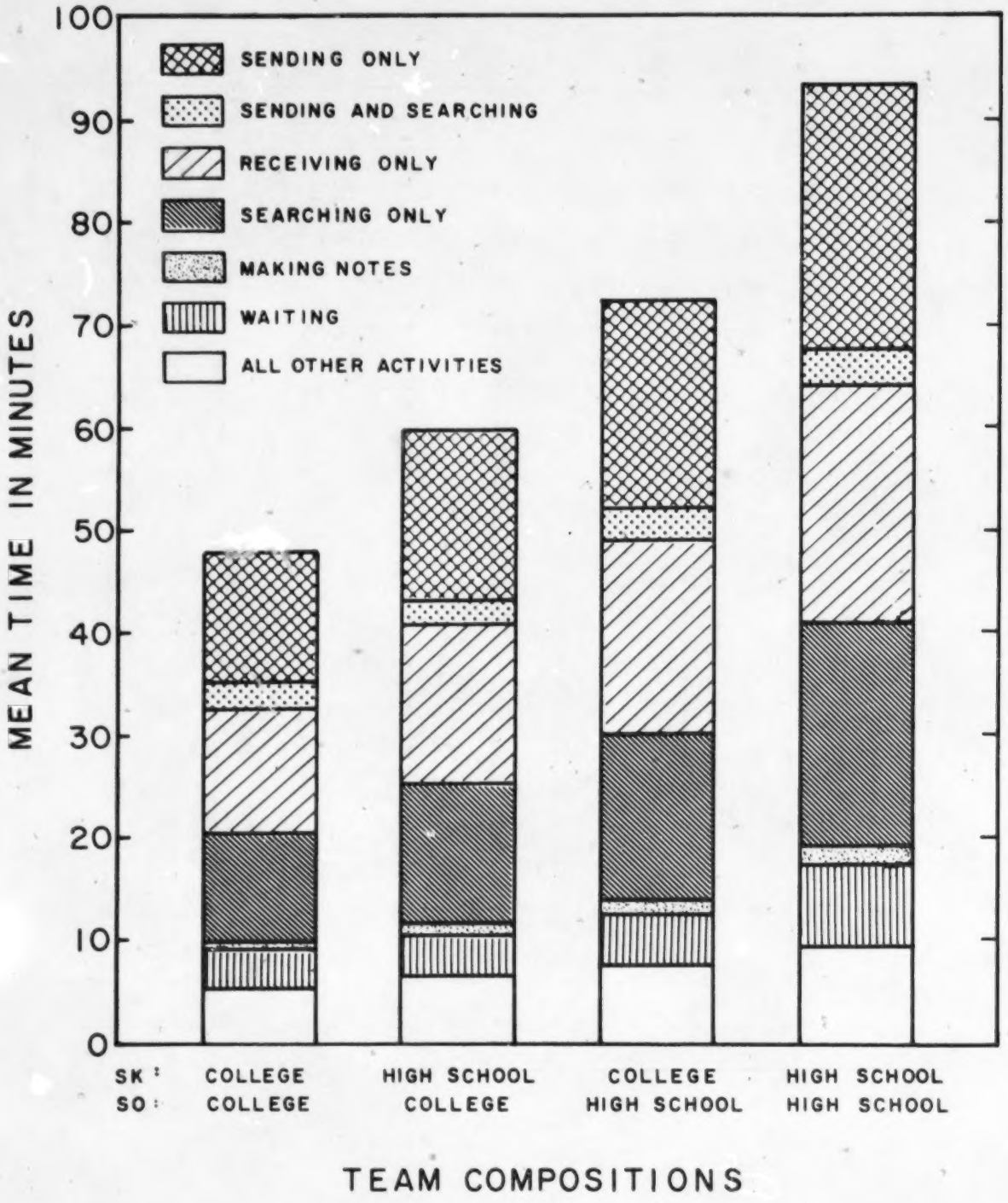

Figure 21. Times to solve problems by combinations of high school and college students. Segments of the bars show the amounts of time spent in each of seven different activities. (From Parrish, 1974)

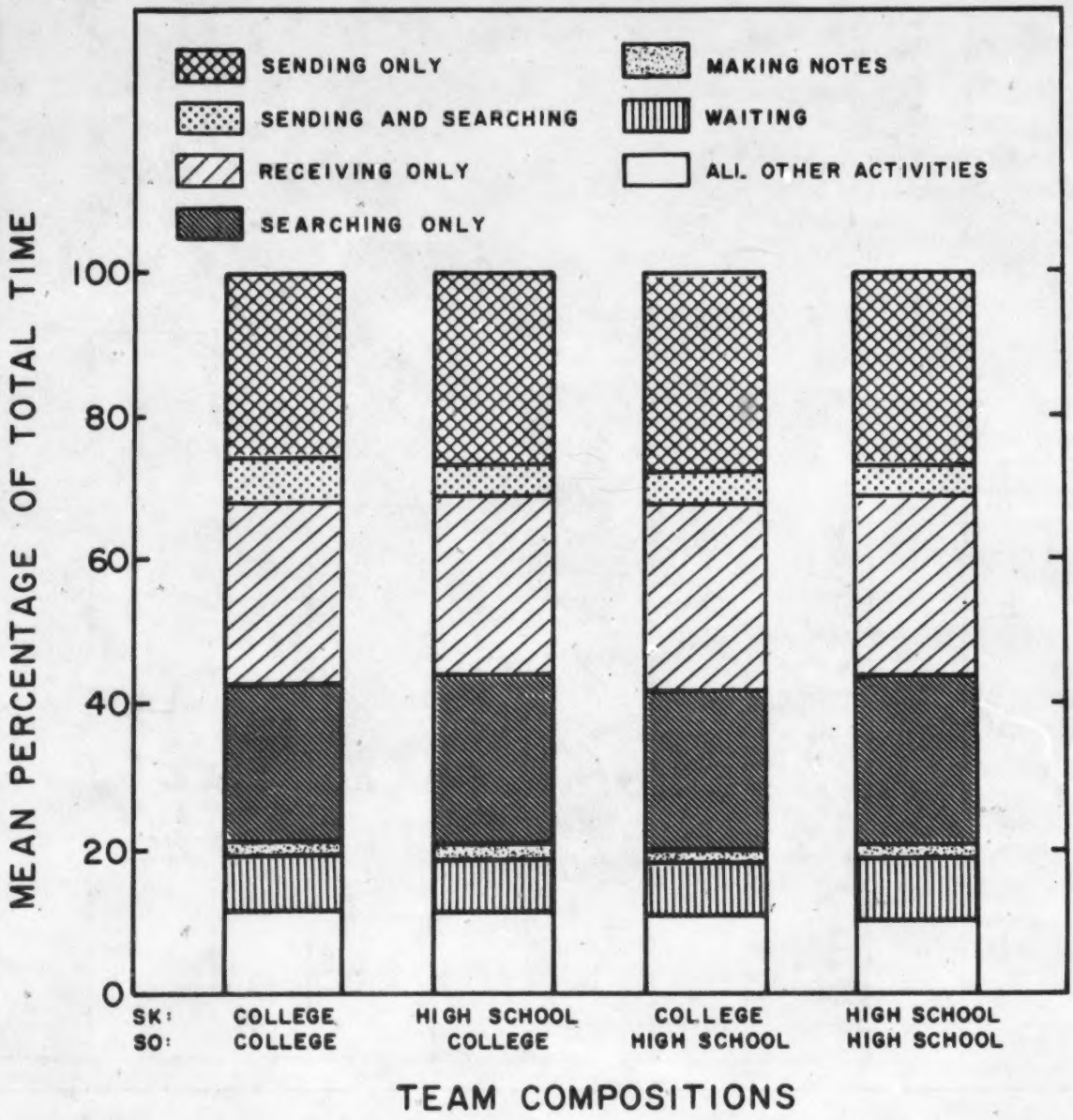

Figure 22. The data of Figure 21 are here represented as percentages. (From Parrish, 1974)

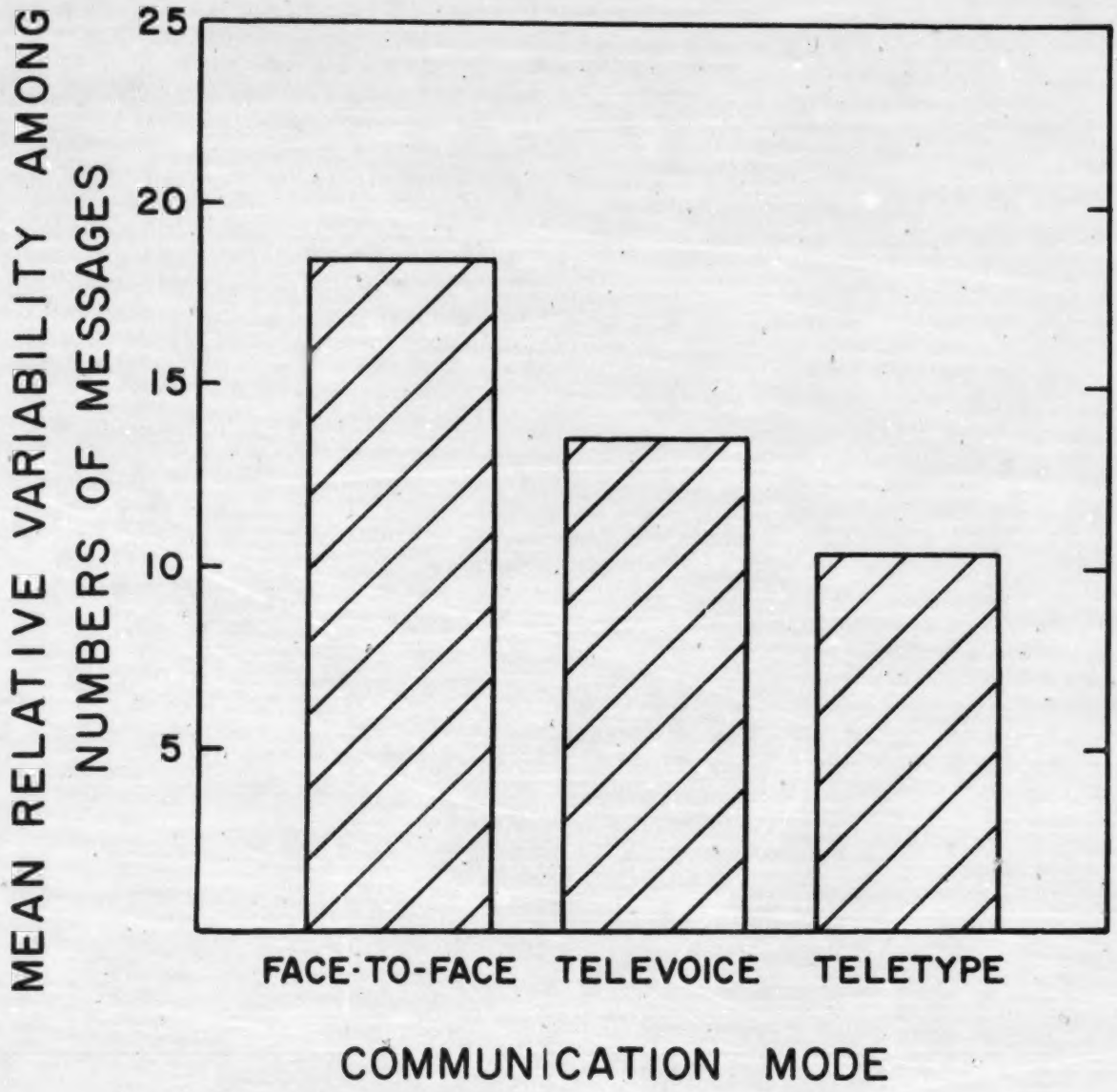

Figure 23. Mean relative variabilities among the numbers of messages produced by communicators in three modes. Each bar is the average of 54 data points. Data are averaged for three sizes of conference group, each of which arrived at solutions to three different problems on each of three successive days. (From Krueger, 1976)

The figure shows that communicators in the teletype mode produced much more nearly equal numbers of messages than did communicators in either of the voice modes. Conversely, in the voice modes, some communicators tended to produce a disproportionately large number of messages, while others tended to be less communicative than would be expected. These data, incidentally, are averages for 2-person, 3-person, and 4-person conferences. Since there was no significant interaction between size of group and communication mode, the data in Figure 23 hold for all three sizes of group.

Linguistic Categories in the Several Modes of Communication

The striking differences in verbal output among the several modes of communication (Refer to Figures 12, 13, 14, and 15, for example) have led us to examine more closely the kind of language and words that are used in the various modes of communication. Here I shall only give two generalizations that seem to emerge from our studies.

13. *We have not been able to find any outstanding differences in the various kinds of words people use in the several modes of communication.*

Figure 24 shows the average numbers of words in each of six linguistic categories based on a modification of the Fries (1952) classification system. These data and those in Figure 12 are from the same experiment. About the only thing one can conclude from Figure 24 is that the differences among the several modes revealed by total word counts appear to hold for words in every linguistic category. Indeed, when the data of Figure 24 are converted to percentages (Figure 25), the prevailing impression one gets is that there are no striking differences among the various kinds of words in the several modes of communication. That impression is confirmed by appropriate statistical tests of the data.

The foregoing notwithstanding, additional studies lead us to conclude that:

14. *Oral communication is highly redundant and most communication can be carried on effectively with a small, carefully selected set of words.*

Because of the nature of natural language communications, redundancy cannot be measured in the ordinary mechanical ways that have been developed from Shannon's theory of information. However, using some plausible assumptions, we have been able to estimate that oral modes of communication use about 12 to 14 times as many words as are necessary and about 4 times as many *different* words as are necessary.

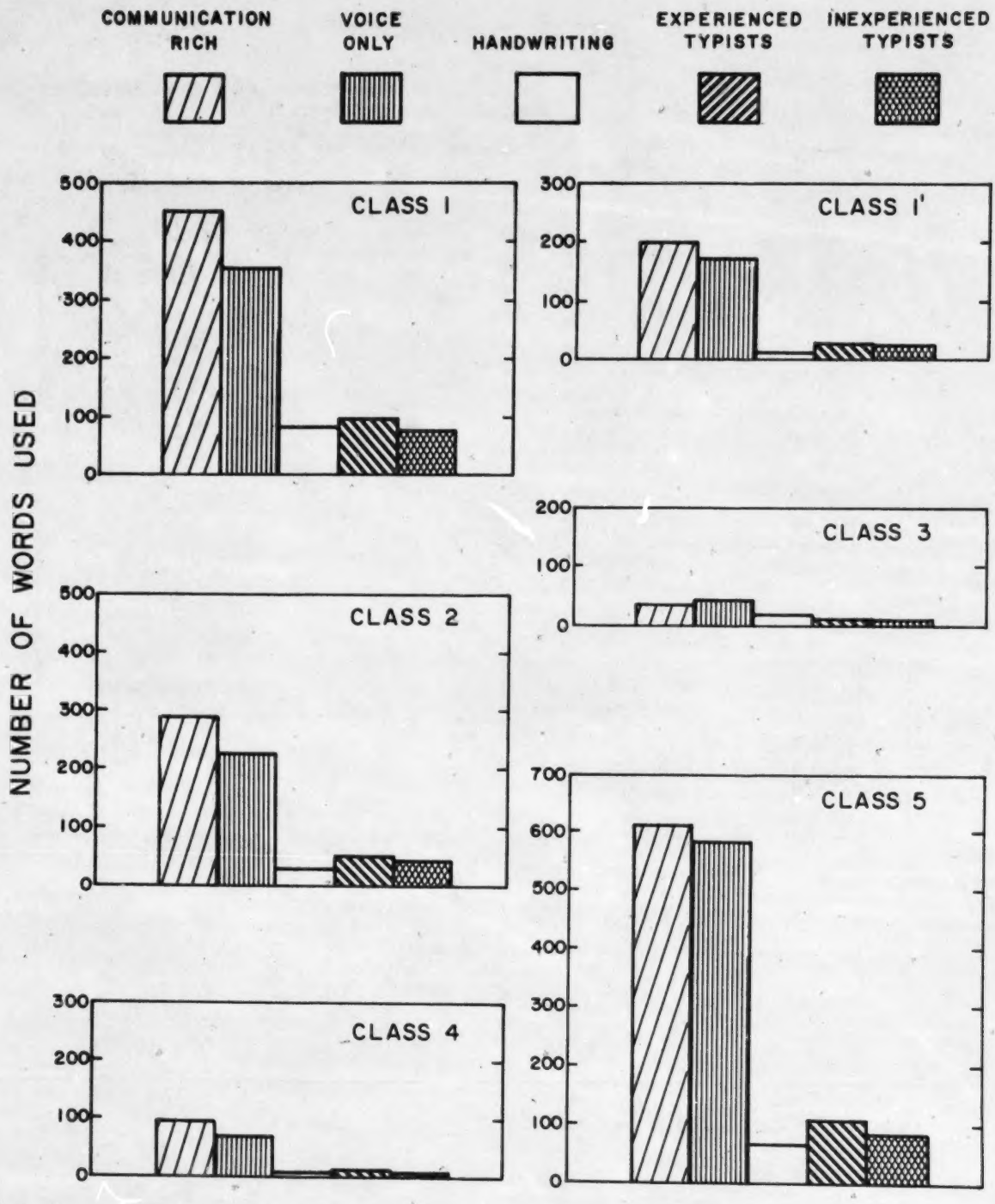

Figure 24. Average numbers of words in each of six linguistic categories by subjects in each of four modes of communication. (From Stoll et al., 1976)

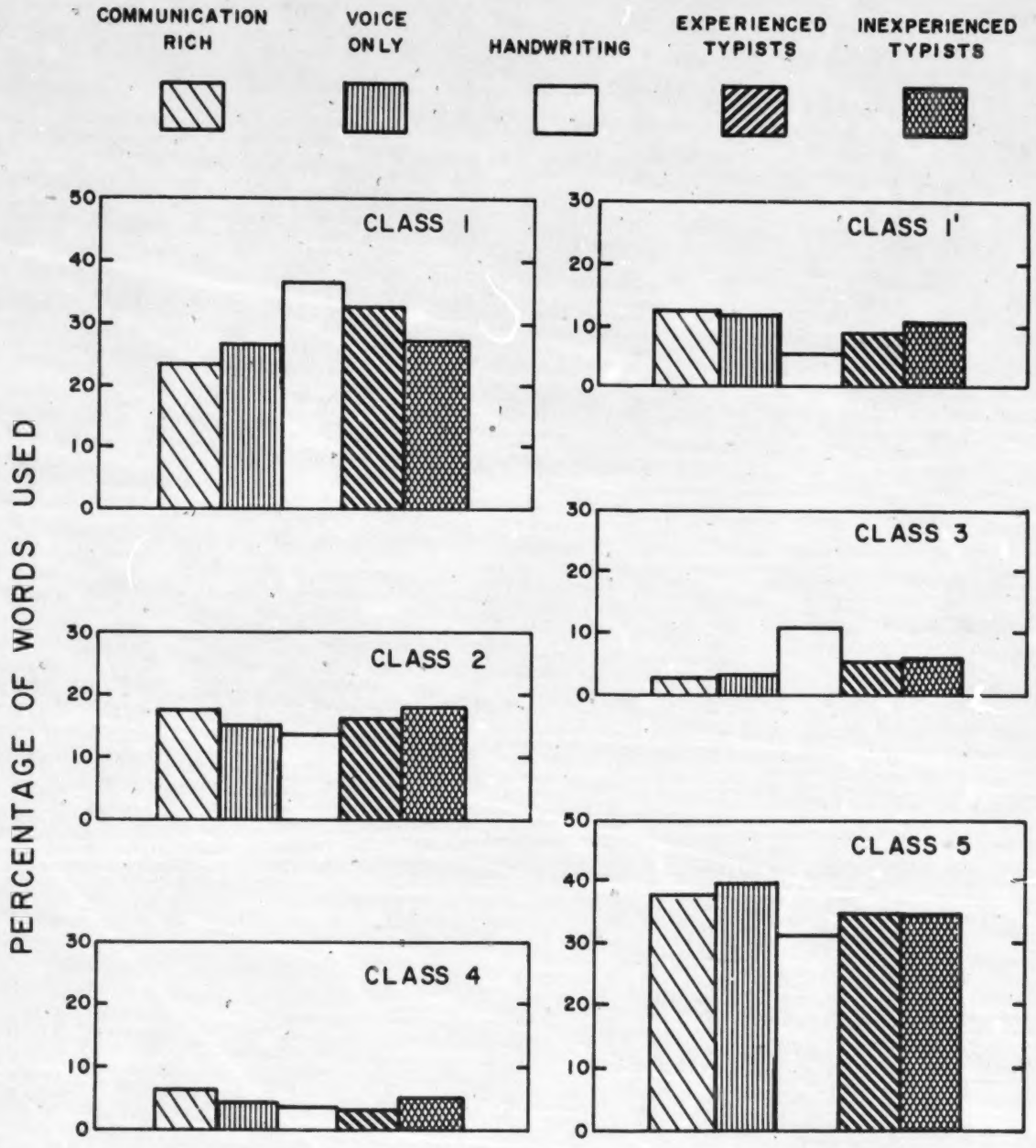

Figure 25. The data in Figure 24 have been here converted to percentages. (From Stoll et al., 1976)

One heartening thing for purposes of man-computer communication is that people can carry out our communication tasks by using no more than 300 words (Kelly, 1976) and can do the tasks just about as fast and about as effectively as they can with no vocabulary restrictions. Let me assert at once, however, that this is a specially selected subset of 300 words. Not any set of 300 will do.

The Effect of Conference Size

One of our experiments (Krueger, 1976) systematically studied two, three, and four persons in three different communication modes: face-to-face, televoice, and teletype. One of the interesting findings of that study is that

> 15. *Verbal productivity, as measured by the number of messages and of words, increased regularly and in almost identically the same manner as the number of conferees increased. Moreover, the increase in verbal productivity was directly related to the number of conferees.*

Some of the data supporting that conclusion appears in Figures 26 and 27. Figure 26 shows the almost linear increase in number of words produced by the group as the number of conferees increased from 2 to 4. These data, incidentally, are averaged for all three modes of communication. However, when the data are expressed in words produced per person (Figure 27), the differences among the various sizes of group disappear. Each addition of another conferee to the group resulted in a relatively constant increase in the number of messages (between 70 and 90) and words (between 825 and 925).

These findings do not mean literally that each person added to a conference group produced the average numbers of words, or of messages, given above. The increase in group verbal productivity as conference groups increase in size may not be directly attributable to the addition of other speakers as to the addition of other listeners. The group verbal output is not shared equally by all persons in a group because the relative disparity among conferees increases as the size of the conference group increases. This suggests that as conference groups increase in size, some people become more silent, and others become more verbal.

Changes over Time

Three experiments (Chapanis & Overbey, 1974; Kelly, 1976; and Krueger, 1976) have tested conference groups for as many as four successive days. Although some statistically significant effects have

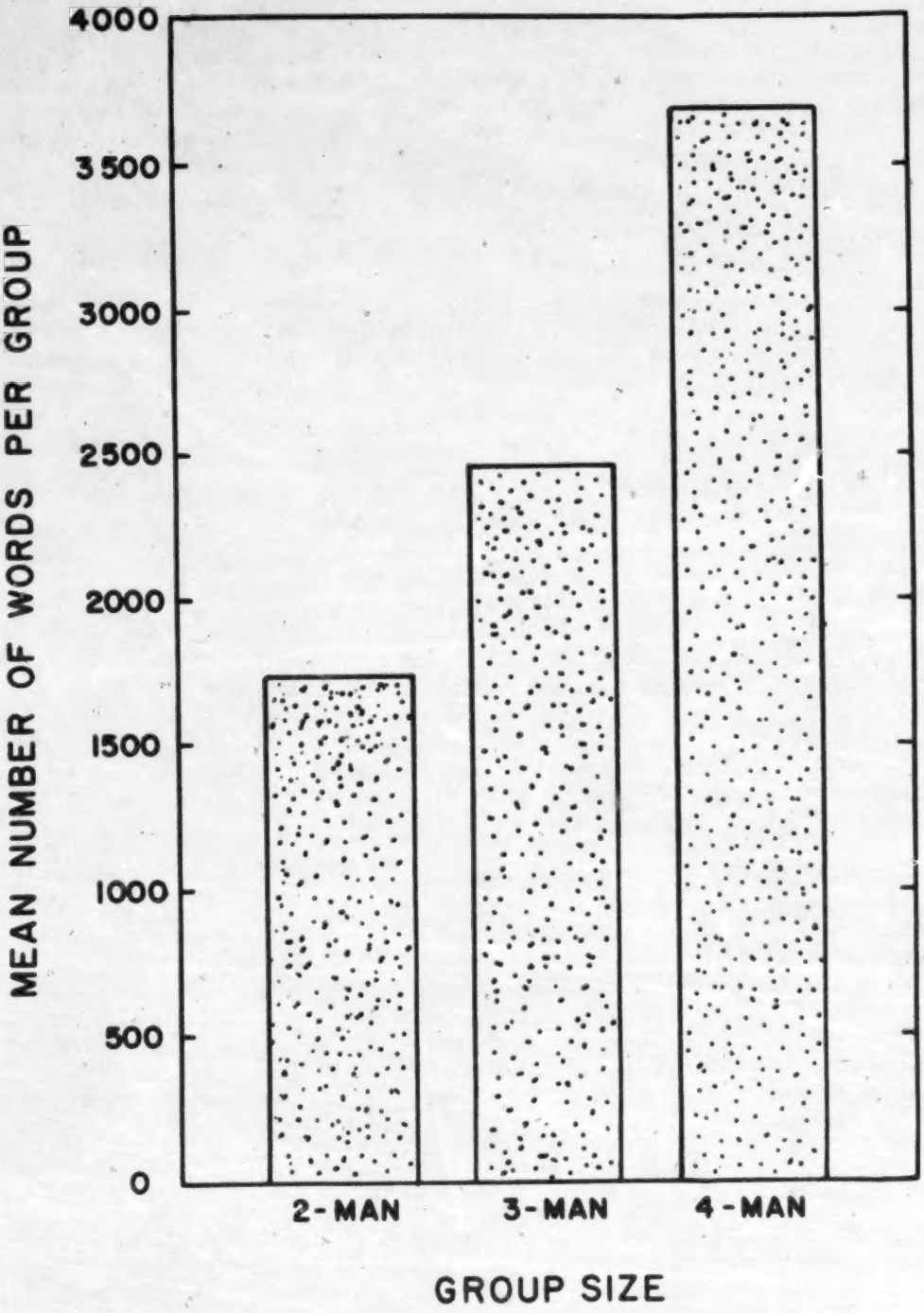

Figure 26. Mean numbers of words produced by groups of two, three, and four persons. These are data averaged for conferences held in three communication modes: face-to-face, televoice, and teletype. (From Krueger, 1976)

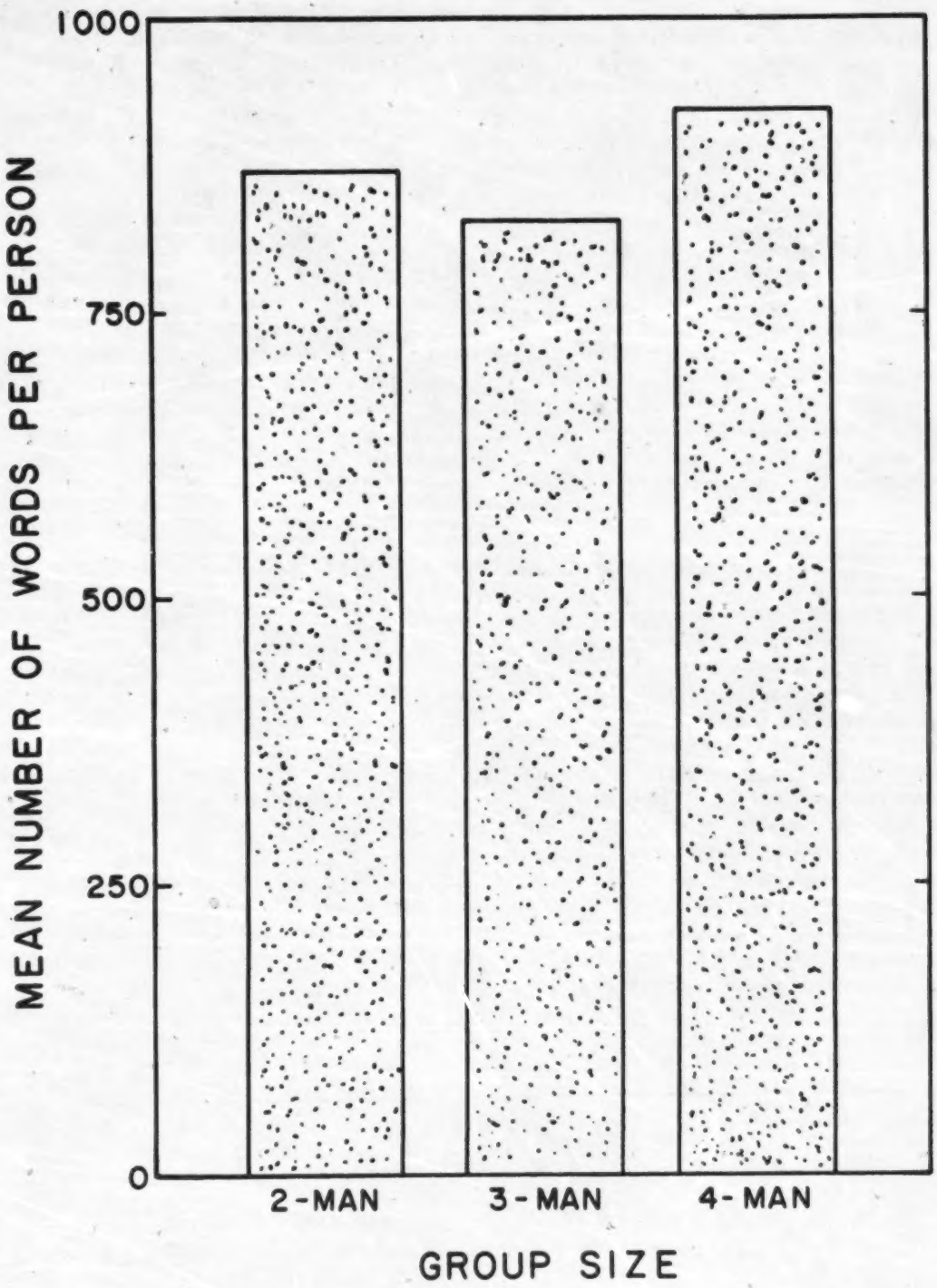

Figure 27. The data in Figure 26 have here been expressed as the average numbers of words produced per person in conference groups of two, three and four persons. (From Krueger, 1976)

turned up in these experiments, the most impressive thing about the findings of these experiments is how few demonstrable changes in performance have occurred from day to day. It is not entirely clear why this is the case. One of the few, almost universal generalizations to come out of psychological research is that performance changes over time. People learn and become more proficient in almost anything they do. Why then are day-to-day changes so few in these experiments?

One reason may be that four days are too few to show changes that are there to be found. As a practical matter, however, it is difficult to design experiments of the kind that we have been doing for periods longer than four days. Once one of our problems has been solved by a conference group, it cannot be used again. We can test on successive days only by assigning a new task each day. To counterbalance for differences among problems, the experimental designs we have used have generally been complex Greco-Latin designs. Although it is technically possible to design large experiments using Greco-Latin squares their administration becomes more and more complex as their size increases.

Another possible explanation for the small number of demonstrable effects we have found from day to day may be that we are testing highly overlearned kinds of performance. Communication in face-to-face meetings, or by talking, and perhaps even by typing, may be such universal skills that there may be virtually nothing new to learn. If this is the case, the finding would have great significance for the introduction of many telecommunication systems.

Still another possible explanation for the lack of demonstrable effects in day to day performance may be precisely because the problems we have given our subjects have varied from day to day (for the reason given above) and that has meant, in essence, that each new problem on each successive day has meant a new learning situation. However, the experiment by Krueger deliberately used three problems that were as nearly alike as possible so that any disturbing effects attributable to the novelty of the problem should thereby be minimized. Even in this case, very few significant effects turned up on successive days of testing.

Clearly, more work needs to be done to clarify why we get so few changes over time, and whether our findings are as valid as they appear to be.

Some Concluding Points

In conclusion, two additional points are worth mentioning about the several experiments discussed in this report.

Statistical and practical significance of the findings. Although statistical matters have not been explicitly discussed in this report, it goes without saying that all of the effects summarized here are significant by appropriate statistical tests. More than that, however, most of the effects are sufficiently large to be of practical importance as well. I mean by that that many of the differences we have found are sufficiently large in absolute magnitude to make them important for practical purposes.

Interrelationships among variables. Most of the effects discussed in this paper have been for so-called main effects, that is, single independent variables with data averaged over a number of other variables. However, all of the experimental designs used in my research program are complex: randomized groups designs involving two or more crossed variables, hierarchical designs, Latin-square designs, and replicated Greco-Latin square designs. The experimental designs we have used all yield data on interactions, or interrelationships among variables. With only three exceptions (Figures 10, 15 and 18), I have chosen to ignore interactions in this report, not because none have turned up, but rather because so few important interactions have turned up involving communication modes. By and large, the effects attributable to communication modes are extremely robust, that is, the differences we have found among the various communication modes appear to hold up for most problems we have tested, for people of diverse abilities, and for successive days of test. That may very well be one of the most significant findings of this program.

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